THREE DIMENSIONAL EVALUATION OF DISCREPANCY BETWEEN MAXIMUM INTERCUSPAL POSITION AND CENTRIC RELATION

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CERTIFICATE

This is to certify that this dissertation titled **"THREE DIMENSIONAL EVALUATION OF DISCREPANCY BETWEEN MAXIMUM INTERCUSPAL POSITION AND CENTRIC RELATION"** is a bonafide record of work done by **Dr. VASHI SHAILENDRASINH MAHENDRASINH** under my guidance during his postgraduate study period between 2008–2011.

This dissertation is submitted to **THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **Master of Dental Surgery** in Branch V –Orthodontics and Dentofacial Orthopedics.

It has not been submitted (partially or fully) for the award of any other degree or diploma.

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CONTENTS

INTRODUCTION

The search for the optimal and preferred types of static and functional occlusions has occupied the minds of dentists for more than a century. The possible role of occlusion in the aetiology of temporomandibular disorders (TMD) also has been the subject of debate.

Much of the occlusion/TMD debate involves issues surrounding centric relation (CR), including definition, recording and measurement, use of articulators and deprogramming splints, and possible relationship to either stomatognathic health or disease.

Over the years, many methods have been developed to study the **TMJ** and the condyle position in the joint space. Some of the conventionally used methods are radiographs, laminographs, tomograms, and magnetic resonance imagings. However, these are not without their limitations as they present only anatomical parameters and ignore the extremely dynamic functions of this complex joint system.

The centric jaw relation (CR) position, in the naturally dentulous state does not usually coincide with the position the mandible assumes when the teeth are in centric occlusion (CO).

Historically, centric relation jaw position has been defined as the most "retruded” contact position[15], but current research indicates that the correct definition is "the relation of the mandible to the cranium that exists when the condyles articulate with the thinnest avascular portion of the respective discs in their most anterior superior position against the slopes of the articular eminences regardless of tooth contact[143]".

"Centric occlusion jaw position "is defined as the most closed position that the mandible assumes, determined by the full intercuspation of opposing teeth, irrespective of condylar position [143]".This potential difference is associated with contradictory theories and is therefore an important topic for further study and understanding.

Since the monograph was introduced by **Posselt**[100] in 1952 concerning the range of the motion of the human mandible, a number of studies have described the movement of the mandible from retruded contact position to maximum intercuspal position.

In 1952 **Sears**[129] studied sagittal, vertical and horizontal changes with the condyle migration recorder.

Possellt[101] used the gnathothesiometer in analyzing the condylar path whereas **Long**[74] used the Buhnergraph to locate the hinge axis and verify the centric jaw relation. **Hoffman, Silverman and Ganfinkel**[61] used a modified articulator to measure differences in condyle position between CR and CO. **Rosneer and Goldberg**[119] used the "vericheck" for 3 dimensional comparison of condylar position in the intercuspal position.

Slavicek[130] described the use of the SAM articulator with Mandibular Position Indicator (MPI) to quantify differences between joint dominated recorded condyle position and the tooth dominated position of maximum intercuspation.

Utt[141] used the Mandibular Position Indicator for 3 dimensional comparison of condyle position between CR and CO. Hinge axis refers to the arbitrary hinge axis and not the true hinge axis.

In the 1970s, **Roth**[120], a gnathologic orthodontist, suggested that orthodontists should embrace the principles of gnathology that had long been held by eminent prosthodontists and restorative dentists. He reasoned that orthodontic treatment is analogous to doing full-mouth occlusal rehabilitation, with the difference being that orthodontics did not “cut” or modify the natural tooth structure. Purveyors of this view were critical of nongnathologic orthodontists for what they saw as their lack of concern about establishing an “optimal” functional occlusion in addition to attaining the long-held traditional goals of static occlusion.

Today’s gnathologically oriented orthodontists advocate the use of articulators with dental casts mounted in anterior-superior CR, with the major goal of orthodontic treatment being to establish coincidence of MI-CR. Accordingly, they believe that the tolerance for MI-CR discrepancies is 1.5 mm in the horizontal (H) and vertical (V) planes and 0.5 mm in the transverse

(T) plane (average: **Utt and colleagues,**[141] 2.0 mm H and V, 0.5 mm T; Crawford,88 1.0 mm H and V, 0.5 mm T).

They further contend that articulator mounted casts, instead of hand-held dental casts, are the only way to discern the MI-CR discrepancies.

For instance, using articulator-mounted dental casts, **Klar and colleagues**[93] found a statistically, but perhaps not clinically, significant change in the pre– versus post–MI-CR recordings (differences of no more than 0.39 mm in any of the three spatial planes) among 200 consecutively gnathologically treated orthodontic patients.

Lastly, gnathologically oriented orthodontists advocate the use of the terminal hinge axis position, the need for pretreatment CR-MI–converted lateral cephalograms and the placement of gnathologic positioners immediately after orthodontic appliances are removed[115,120,121].

A two-piece bite registration technique by **Roth**[121] called the "power centric bite registration" is believed to seat the condyles in the optimal, anterior-superior CR position—or as **Utt and colleagues**[141] wrote, "condyles centered transversely and seated against the articular disk at the posterior slope of the articular eminences without dental interferences."

Harmony of form is a prerequisite for harmony of function. There is no such thing as a perfect occlusion with a displaced TMJ. The peaceful function of the masticatory musculature depends on the harmonious relationship between the occlusion and the TMJ.

Stability is one of the treatment goal of orthodontic treatment, and to get to that, a gnathological approach is necessary. Establishing equilibrium between the teeth and the neuromusculature is critical because whenever there is disequilibrium, the muscles will attempt to regain it. The evidence of this is excessive tooth wear, tooth hypermobility, periodontal break down in the presence of good oral hygiene.

If treatment goals include condyles seated in the fossa and an occlusion that will not interfere with condylar border movements, then it is essential to assess the occlusion with the condyles in centric relation.

This study was thus conducted with the aim of establishing the discrepancy between Maximum Intercuspation (MI) and Centric Relation (CR) in post orthodontic patients and to statistically evaluate the range of deviation from the accepted norms.

REVIEW OF LITERATURE

Literature has been reviewed under the following headings:

- Centric relation, Centric occlusion, maximum intercuspation and concept of Functional occlusion
- Occlusal Interferences and TMD
- Malocclusion and TMD
- Orthodontic treatment and TMD
- Condyle and Disc position
- Methods of evaluating TMJ
- Recording Maxillo mandibular Relations

- ***<u>Centric relation, Centric occlusion, maximum intercuspation and concept of Functional occlusion</u>***

Dentistry has not arrived at a consensus definition and concept of CR. In 2004, **Christensen**[20] said that he and most practitioners “accept the concept that CR is the most comfortable posterior location of the mandible when it is bilaterally manipulated gently backward and upward into a retrusive position.” However, CR has not been recognized as a posterior, retruded condyle position for almost 20 years [41]**.**

In 2000, **Jasinevicius and colleagues**[63] found that faculty and students at seven dental schools could not agree on a unified definition of CR. The definition of centric relation has changed numerous times over the years. The definition of CR has evolved over the past Half-century from being a posterior and superior position of the condyle in relation to The glenoid fossa to an anteriorsuperior position. Glossary of Prosthodontic terms published in the Journal of prosthetic dentistry has had six editions[15, 56, 41,143]**.**

Definition for CR and CO in 1st, 3rd, 5th and 6th edition of the glossary is as follows:

1st Edition (1956)[15]

CR - Most retruded relation of the mandible to the maxilla when the condyles are in the most posterior unrestrained position in the glenoid fossa from which lateral movements can be made, at any given degree of jaw separation.

CO - Not defined

3rd Edition (1969)[56]

CR - Most retruded physiologic relation of the mandible to the maxilla to and from which the individual can make lateral movements. It is a condition, which can exist at various degrees of jaw separation. It occurs around the terminal hinge axis. The most posterior relation of the mandible to maxilla at established vertical relation.

CO - Centered contact position of the lower occlusal surfaces against the upper ones, a reference position from which all other horizontal positions are eccentric.

5th Edition (1987)[41]:

CR - A maxillo mandibular relation in which condyles articulate with the thinnest vascular portion of their respective disks with the complex in the anterior superior position against the slopes of the articular eminences. This position is independent of tooth contact. This position is clinically discernible when the mandible is directed superiorly and anteriorly and restricted to a purely rotary movement about a transverse horizontal axis.

CO - Occlusion of opposing teeth when the mandible is in CR. This may or may not coincide with maximum intercuspation position.

Maximum intercuspation (MI) : the complete intercuspation of opposing teeth independent of condylar position[143] .

6th Edition (1994)[143]: Same as the 5th edition.

***Parker (1978)*[98]** states that contacts, which occur on the non working - side are not only damaging to the periodontium but probably also contribute to the TMJ syndrome.

***Roth (1981)*[120]** has advocated the importance of treating patients in centric relation emphasizing the. relationship between temporomandibular dysfunction and occlusal interferences since the 1970s.

***Williamson (1981)*[151] in** an interview on occlusion and **TMJ** dysfunction states that in centric relation both mandibular condyles are simultaneously seated more superiorly on the posterior slope of the articular eminences, with the menisci interposed properly in between. They are placed in that position by the patient's own healthy musculature, which is contracting evenly on both sides. **It** is referred to as CR, and is prior to first tooth contact.

Centric relation at first tooth contact is referred to as centric relation occlusion (CRO) or retruded contact position (RCP). Williamson defines CO as that position of the mandibular condyles when the teeth are in maximum intercuspation.

However the glossary of prosthetic dentistry defined maximum intercuspation as "the complete intercuspation of the opposing teeth independent of the condylar position".

Gelb's (1985)[50] concept for preferred CR position was one in which the condyle translated approximately half way down the posterior slope of the articular eminence i.e. anterior mid condylar position.

Okeson (1989)[95] advocated an anterior superior condylar position and believed it to be the most stable joint position and also the musculoskeletally stable position.

In the past, gnathologists suggested ' rearmost, uppermost and midmost" to describe the condyle position in centric relation.

Dawson (1989)[26] has stated that"rearmost and uppermost' is an incorrect description because the condyles cannot be in the rearmost position when they are in the "uppermost" position and vice versa. He has suggested that the condyles should be positioned most superiorly and anteriorly against the posterior slope of the eminence when in centric relation.

Pfeiffer - Flor and Pancherz (1991)[99] in an extensive review concluded that canine guidance occlusion is just as acceptable as group functioning occlusion. In addition, a natural dentition with canine guidance occlusion will tend to become group functioning with time, due to wear of the maxillary canine.

Roth (1995)[123] has suggested that the diagnosis and treatment planning of orthodontic patients must be made with the mandible in centric relation because orthodontic treatment is essentially full mouth reconstruction of the patients own dentition.

Ramfjord and Ash (1995)[108] Centric relation (CR) is a defined mandibular position from which interocclusal relationships are analyzed.

Cecere, Reef, and Pancherz (1996)[19] investigated EMG recordings (of the anterior temporal and masseter muscles) when several factors were varied: relocation of the electrodes between readings, the effect of not removing electrodes and the use of new electrodes were compared following various chewing / biting activities. They found that, depending on the time interval between recordings, the muscles considered, and the function performed, individual errors ranged from 5% to 63%. The method error increased significantly with a time interval between recordings. They stated that quantitative electromyography of the masticatory muscles seems to have limited value in diagnosis and in the evaluation of individual treatment results.

Truitt, Strauss and Best (2009)[140] conducted a study to determine whether there is a consensus among oral and maxillofacial surgeons and orthodontists as to the definition of centric relation. There was no difference between the 2 groups on the need for mounting models in centric relation for use in orthognathic surgery. Regarding the definition of centric occlusion, there was a significant difference between orthodontists and surgeons. The results of this study show that there is a statistical lack of consistency among practitioners regarding an absolute definition of centric relation as it relates to orthognathic surgery. The inconsistency exists between specialties and within practitioners in each specialty

Weffor and Solange Mongelli de Fantini (2010)[158] conducted a study to measure condylar displacement between centric relation (CR) and maximum intercuspation (MIC) in symptomatic and asymptomatic subjects. And concluded that

- When the plane and the direction of the displacement were considered, statistically significant differences between CR and MIC were quantifiable at the condylar level in symptomatic and asymptomatic individuals.
- No statistical differences were noted between genders

- **Occlusal interferences and TMD:**

Ziebert and Donegan (1979)[160] investigated 10 subjects (age range 20 to 64) who required occlusal adjustment to eliminate non working - side contacts (among other occlusal features). Study models were taken before and after occlusal grinding and 6 weeks later. Silicone putty interocclusal records (taken in ICP and RCP) were taken and repeated until identical records were obtained at each stage. Six patients, each with a full compliment of teeth (excluding third molars), showed no clinically perceptible slide from CR to CO 6 weeks after the occlusal adjustment, but four patients (those who had a missing tooth but with spaces closed) had occlusions that had relapsed after adjustment.

Agersberg and Sandstrom (1988)[2] found that 75% of 15 and 22 years old subjects had unilateral tooth contacts in retruded position. 88% and 89% respectively, of the individuals in both age groups had at least one occlusal contact, usually defined as an interference in one or more of the nine registered positions of the mandible. None had TMD.

Mohl and Ohrback (1992)[87] suggested that occlusal adjustments should no longer be used in the management of TMDs. Their arguments include the irreversibility and invasiveness of occlusal adjustment, the lack of evidence for the causal role of occlusal factors, the reported good short- term results of reversible therapies, and the high probability of spontaneous recovery.

Kirveskari (1997)[71] showed that several controlled clinical trials have failed to disprove the etiologic role of occlusion in TMDs. These trials also suggest an effect for occlusal adjustment on chronic headaches and on chronic neck and shoulder pain in comparison with conventional treatments. Long-term studies have disclosed no adverse effects of occlusal adjustment apart from transient tooth sensitivity in a very small number of cases. In view of the possibility that occlusal factors have a causal role in TMDs, research efforts on the role of occlusion should be intensified, and teaching should be revised accordingly.

Luther (1998)[77] in his extensive review has questioned the validity of the results obtained by a few researchers to assess the effect of an artificially introduced interference, often using electromyography. He states that a number of weaknesses are present, and whether they actually reflect the natural situation is debatable. Not all studies provide details of the size of the interference and where this is described, the magnitudes are large (0.05mm high, Riise and Sheikholesam, 0.05 to 0.75 mm, Christensen and Rassouli). Some of the other weaknesses are a small sample size and their background (student nurses and hygienists) might *have* influenced the subjects.

Luther concluded in his *review* that there are no long-term studies investigating the *longevity* of a functional occlusion following orthodontic treatment. If it is suggested that functional occlusion be a treatment aim for all cases one must question the stability of this goal and address the problem of whether repeated grinding to maintain it is a suitable form of treatment. There is little evidence to show whether functional occlusion IS always stable. Aubrey despite advocating a functional occlusion as a treatment aim suggested that teeth *move* despite this and may need repeated grinding. The works of Forsell et al, and Kirverskari et al also acknowledged this where repeated occlusal adjustments were needed.

Pahkala and Laine (2002)[97] conducted a study to focus on if early signs of different orofacial dysfunctions, e.g. misarticulations of speech, problems in oral motor skills and TMD, malocclusions or occlusal interferences could predict the development of temporomandibular disorders (TMD) in adolescence. Altogether there were 94 children referred for speech therapy and 93 controls who participated in all three stages of this longitudinal study. In the whole sample the mean age during the first examination was 7.6 years, during the second examination 10.6 years, and during the third one 15.4 years.Deviation on opening was associated with problems in oral motor skills, and some signs of TMD seemed to be related to each other. In addition, girls had a higher risk of having several signs of TMD than boys did. In conclusion, tendency to open bite, both mesial and distal molar occlusion and increased and decreased overjet were occlusal anomalies associated with TMD. Altogether, among 15-year-olds there seems to be both local and central factors in the aetiology of TMD.

Barker (2004)[9] in his study sought to determine how a balanced occlusion, providing uniform contact in centric relation, would affect signs and symptoms of TMD. A randomly chosen group of 60 patients with occlusal interferences and signs and symptoms of TMD used a mandibular orthotic to balance their occlusions at centric relation (CR). When the occlusions of symptomatic patients were balanced in CR, there was a significant reduction or elimination of TMD complaints, suggesting a relationship between balancing occlusion in CR and optimum management of TMD.

Bonjardim and Lopes-Filho (2009)[14] conducted a study was to find out the prevalence of temporomandibular disorder (TMD) in a sample of university students and its relationship to gender, occlusion, and psychological factors. According to our results, 50% of the subjects had TMD, but it was of moderate or severe degree in only 9.18% of them. No statistically significant association could be found between TMD and gender or occlusion. TMD was found to have statistically significant association with HADSa (anxiety) but not with HADSd (depression).

- **Malocclusion and TMD:**

Mohlin and Kopp (1978)[88] conducted a study on 56 patients with TMD between the age group of 16 to 62 years and noted that 16.1 % of the sample had anterior open bite, 5.4% of the sample had deep overbite and 16.1 % of he sample had increased overjet. He found that 16% of the patients had unilateral crossbite and 16% of the patients had bilateral crossbite. Mohlin and Kopp reported a positive correlation between crossbite and interferences between RCP and ICP and mediotrusion interferences. He also found that 8.5% had Class I occlusion, 19.7% had Class II occlusion and only 1.8% had Class III occlusion.

Pullinger et at (1987)[105] investigated 44 young adults (with a variety of malocclusions) with no history (or signs or symptoms) of TMD and no orthodontic or other occlusal therapy. Using corrected lateral tomograms, they found that 25% of the adults with Class I malocclusion had posteriorly positioned condyles, 18% had anteriorly positioned condyles, and 57% had concentrically placed condyles.

Egermark - Eriksson et at (1990)[34] followed 238 subjects on a longitudinal basis for 4 to 5 years. Three different age groups were involved (7, 11 and 15 years old). Few significant correlations were found in any age group between morphological and functional malocclusions, but the oldest group showed a significant positive correlation between postnormal occlusions and large anteroposterior distance between RCP and ICP. In the different age groups, non working-side interferences were significantly correlated with and number of malocclusions associated with anterior open bite, but most of the correlations lay for such features as lateral open bite and posterior crossbite. The authors state that correlations were generally weak and only a few were significant (the strongest included unilateral crossbite and extreme maxillary overjet).

Cohlmia, Ghosh, and Nanda (1996)[22] evaluated the morphologic relationship of the condyle and fossa in patients with different malocclusions and skeletal relationships. Pretreatment records of 232 orthodontic patients ranging in age from 9 to 42 years were examined. Records included dental casts, lateral cephalometric radiographs, hand wrist radiographs and corrected tomograms of right and left TM joints.

- Non concentricity and mild asymmetry of the condyle fossa relationship were commonly observed
- Left condyle was found to be more anteriorly positioned than the right with he mean joint space being 6.93% on the left and -1.24% on the right
- Skeletal and dental Class III patients demonstrated significantly more anteriorly positioned condyles
- No significant difference in condylar position between Class I and Class II groups based on ANB or Angles classification

No significant difference in condylar position between group based on overbite or crossbite.

Thor, Ekberg, and Nilner (1998)[139] evaluated the masticatory efficiency and mandibular dysfunction in a total of 183 girls, aged 11 to 15 years. Six subjects had normal occlusion and 123 subjects had Class II malocclusion. Examination included registration of signs and symptoms of TMD. Subjects with normal occlusion presented significantly better masticatory efficiency and ability than subjects with Class II malocclusion. Few occlusal contacts and a large overjet predicted a reduced masticatory efficiency. Subjects who reported frequent TMJ clicking and subjects who estimated their overall symptoms of TMD as moderate or severe also had reduced masticatory efficiency. The authors concluded that masticatory efficiency and ability was partly dependent on the occlusion and those symptoms of TMD influenced the masticatory efficiency and ability.

Mohlin and Pilley (2004)[90] performed a study in which A total of 1018 subjects were examined at the age of 11 years, 791 were reexamined at 15 years, 456 at 19 years, and 337 at 30 years. Anamnestic and clinical recordings of temporomandibular disorder (TMD) were made. Morphology, including calculation of peer assessment rating (PAR) scores, was recorded. Previous history of orthodontic treatment was assessed. Muscular endurance was recorded. The subjects completed four psychological measures. The malocclusion prevalence, occlusal contacts, psychological factors, and muscular endurance in subjects with no recorded signs and symptoms of TMD were compared with those with the most severe dysfunction at 19 years of age. The further development of TMD to 30 years of age was followed. PAR scores were significantly higher in the subjects with the most severe dysfunction. Apart from crowding of teeth, no other significant differences were found between the groups with regard to separate malocclusions, tooth contact pattern, orthodontic treatment, or extractions. A greater proportion of subjects with low endurance were found in those with TMD. Significant associations between TMD and general health and psychological well-being as well as the personality dimension of neuroticism and self-esteem were found.

Mackie and Lyons (2008)[80] conducted a review of literature about the role of occlusion on TMD. Unfortunately, there appears to be no consensus regarding the definition of a temporomandibular disorder within the literature (Mohlin and Thilander, 1984; Okeson, 2003a), and there is considerable variation among epidemiological studies. These studies report that between 5 and 50% of individuals experience TMD pain (Dworkin and Massoth, 1994), with females comprising 75% to 84% of those affected (Dworkin et al., 1990). This may be related to differences in pain measurement criteria or study design, and women tending to present for treatment more readily than men.

Jerjes and Upile (2008)[65] conducted a study to explore the etiology of temporomandibular disorders and discusses the controversies in variable treatment modalities.Pathologies of the temporomandibular joint (TMJ) and its' associated muscles of mastication are jointly termed temporomandibular disorders (TMDs).TMDs present with a variety of symptoms which include pain in the joint and its surrounding area, jaw clicking, limited jaw opening and headaches. It is mainly reported by middle aged females who tend to recognize the symptoms more readily than males and therefore more commonly seek professional help. Several etiological factors have been acknowledged including local trauma, bruxism, malocclusion, stress and psychiatric illnesses. The Research Diagnostic Criteria of the Temporomandibular Disorders (RDC/TMD) is advanced to other criteria as it takes into consideration the socio-psychological status of the patient. Several treatment modalities have been recommended including homecare practices, splint therapy, occlusal adjustment, analgesics and the use of psychotropic medication; as well as surgery, supplementary therapy and cognitive behavioral therapy. Although splint therapy and occlusal adjustment have been extensively used, there is no evidence to suggest that they can be curative; a number of evidence-based trials have concluded that these appliances should not be suggested as part of the routine care. Surgery, except in very rare cases, is discouraged since it is the most invasive alternative; recent studies have shown healthier outcome with cognitive behavioural therapy.

- **Orthodontic treatment and TMD:**

Sadowsky and Begole (1980)[124] evaluated the status of TMJ function and functional occlusion by means of a questionnaire and a detailed clinical examination in a group of 75 subjects. These subjects were between 25 and 55 years of age who had been treated orthodontically with full fixed appliances at least 10 to 35 years previously, during adolescence. The findings were compared with those of the control group adults with untreated malocclusion. Findings indicate that in patients who underwent orthodontic treatment many years previously the prevalence of TMJ signs and symptoms similar to that of control group of adults with untreated malocclusions. However a trend exists which suggests that subjects who had undergone extensive fixed appliance orthodontic treatment many years previously may possibly have a lower prevalence of TMJ problem than a similar group of adults with untreated malocclusions.

Sadowsky and Polsen (1984)[125] studied the relation between TMD and functional occlusion after orthJdontic treatment. The findings from the total sample of 96 orthodontically treated subjects as compared with 103 controls 'rom the Illinois study group was contrasted to the findings from an independent study on 111 subjects who received orthodontic treatment at .east 10 years previously and were compared with 111 adults with untreated malocclusion. Non extraction and extraction cases were well represented in the above studies. The findings were very similar in both studies with the prevalence of symptoms varying between 15% to 21 % and 29% to 42% for signs Ooint sounds), there being no statistically significant differences between treated and untreated subjects in either of the studies. The conclusion from the above two studies was that orthodontic treatment performed during adolescence did not generally increase the risk of developing TMD in later life.

Wyatt (1987)[156] recommemded the following for the diagnosis and treatment planning of orthodontic patients.

1) Etiologic factors that might cause upward and backward pressures on the mandible should be reduced as much as possible.

2) Mechanotherapy that may cause upward and backward pressures on the condyles is not recommended. Final detailed correction of dental abnormalities should always consider optimal temporomandibular health and function.

Gianelly, and Hughes (1988)[52] evaluated the condylar position with corrected tomogram before orthodontic treatment in 37 consecutive patients between the ages 10 and 18 yaars and compared them with 30 consecutively treated four premolar extraction cases at the completion of treatment. All patients were treated with fixed appliances, 23 with Edgewise and 7 with Begg technique. They could find no difference in condylar position between the extraction and the untreated groups. It was concluded that extraction therapy did not appear to be an iatrogenic cause of distally positioned condyles. Condylar position tended to be centered on average; however a wide variation in position was noted.

Heikinheimo, Salmi, Myllarniemi, and Kirveskari (1989)[45] followed 167 subjects from ages 12 to 15 years and found that symptoms of craniomandibular disorders (CMD) did not change in 38% of subjects, increased in 32%, and decreased in 31 %. Half of those exhibiting clicking at the age of 12 years lost the clicking by the age of 15 years.

Gianelly (1989)[40] summarized the problem said to arise following certain forms of orthodontic treatment. According to him, an iatrogenic cause of posterior condylar position is premolar extraction in orthodontic treatment. Moreover, posterior condylar position within the fossa is associated with an anteriorly displaced disc. He pointed out that it is not clear whether posterior positioning of the mandible leads to internal derangement or vice versa. Gianelly cited the work of Farrar and McCarty (1983) who proposed that a space of less than 2.4mm posterior to the condyle on a transcranial x-ray suggested an internal derangement.

Sadowsky and Theison (1991)[126] reported on their prospective longitudinal study of 160 patients with an average age of 14 years, treated with full fixed appliances for an average of 35 months. Of the 160 patients, 54% were treated with an extraction treatment strategy and 42.5% were treated with nonextraction. In addition to recording symptoms, joint sounds, were objectively recorded with an audiovisual videotape system. Before treatment 25% of the patients had joint sounds, whereas 16.2% had sounds after treatment. In 27 patients the sounds were not evident after treatment, in 3 patients there was no change in occurrence, and sounds developed in 13 patients by the end of treatment. Before treatment 14% of the patients had reciprocal clicking, where as only 8% had reciprocal clicking after treatment.

Sadowsky (1992)[127] studied the risk of orthodontic treatment producing TMD. His findings represented approximately 1300 previously treated orthodontic patients from different regions of the world, treated with varying strategies including extraction and nonextraction approaches, and various appliance systems both fixed and removable. While most were cross sectional studies some prospective longitudinal studies existed. The overwhelming evidence supported the conclusion that orthodontic treatment performed on children and adolescents was generally not a risk for the development of TMD years later.

Morrant and Taylor (1996)[92] studied the prevalence of TMD in patients referred for orthodontic assessments. Three hundred and one unselected orthodontic referrals were assessed for TMD, using a standardized questionnaire and clinical examination protocol. The mean age of the patients was 13.4 years. Over one third of the 301 patients were found to exhibit at least one sign of TMD, and two thirds had a mandibular dysfunction index (MDI) score of 1, 2 or 3, indicating mild to moderate dysfunction, only five patients were found to have severe temporomandibular dysfunction. Statistically significant relationship was found between patient age and mandibular opening, and TMJ noises. No relationship was found between signs detected by clinical examination and symptoms reported by the patients.

Williams (1998)[147] in his study determined pretreatment and posttreatment condylar stability on forty TMD patients with symptoms of pain in the muscles of mastication, TMJ sounds, attrition, interceptive occlusal contacts and restricted range of motion. Axial corrected midcut sagittal tomograms were made for the 80 temporomandibular joints before treatment. Tracings from the tomograms. were used to measure and analyze pretreatment position and posttreatment stability. Results showed that pretreatment condyle fossa position was not concentric in 26 to 80 patients (32.5%). Posttreatment condylar position showed no change and was statistically stable

Kim and Graber (2002)[68] conducted a meta-analysis to investigate the relationship between traditional orthodontic treatment, including the specific type of appliance used and whether extractions were performed, and the prevalence of temporomandibular disorders (TMD) was investigated. After an exhaustive literature search of 960 articles, we found 31 that met the inclusion criteria (18 cross-sectional studies or surveys and 13 longitudinal studies). We divided and extracted data from the 31 articles according to study designs, symptoms, signs, or indexes. Due to severe heterogeneity, the results were summarized without further statistical analysis. The heterogeneous result might originate from lack of a universal diagnostic system and the variability of TMD. Because of heterogeneity, a definitive conclusion cannot be drawn. The data included in this comprehensive meta-analysis do not indicate that traditional orthodontic treatment increased the prevalence of TMD. It is apparent that a reliable and valid diagnostic classification system for TMD is needed for future research.

Henrikson and Nilner (2003)[55] conducted a study to To prospectively and longitudinally study symptoms and signs of temporomandibular disorders (TMD) and occlusal changes in girls with Class II malocclusion receiving orthodontic fixed appliance treatment in comparison with untreated Class II malocclusions and with normal occlusion subjects. Prospective observational cohortSixty-five girls with Class II malocclusion who received orthodontic treatment, 58 girls with no treatment, and 60 girls with normal occlusion. The girls were examined for symptoms and signs of TMD and re-examined 2 years later. Additional records were taken in the orthodontic group during active treatment and 1 year after treatment. All three groups included subjects with more or less pronounced TMD, which showed individual fluctuation during the ongoing study. In the orthodontic group, the prevalence of muscular signs of TMD was significantly less common post-treatment. Temporomandibular joint clicking increased in all three groups over the 2 years, but was less common in the normal group. The normal group also had a lower overall prevalence of TMD than the orthodontic and the Class II group at both registrations. Functional occlusal interferences decreased in the orthodontic group, but remained the same in the othother groups over the 2 years.

Abrahamsson and Ekberg (2007)[1] conducted a study to answer the question whether orthognathic surgery does affect the prevalence of signs and symptoms of temporomandibular disorders (TMDs). The search strategy resulted in 467 articles, of which 3 met the inclusion criteria. Because of few studies with unambiguous results and heterogeneity in study design, the scientific evidence was insufficient to evaluate the effects that orthognathic surgery had on TMD. Moreover, the studies had problems with inadequate selection description, confounding factors, and lack of method error analysis.To obtain reliable scientific evidence, additional well-controlled and well-designed studies are needed to determine how and if orthognathic surgery alters signs and symptoms of TMD.

Slade and Diatchenko (2008)[132] published in seminars in orthodontics, genetic markers can be of additional value in identifying gene-environment interactions, that is, isolating population sub-groups, defined by genotype in which environmental influences play a relatively greater or lesser etiological role. This paper reviews concepts and study design requirements for epidemiological investigations into TMD etiology. Findings are presented from a prospective cohort study of 186 females that illustrate an example of gene-environment interaction in TMD onset. Among people with a variant of the gene encoding catechol-O-methyl-transferase, an enzyme associated with pain responsiveness, risk of developing TMD was significantly greater for subjects who reported a history of orthodontic treatment compared with subjects who did not (P=0.04). While further studies are needed to investigate TMD etiology, this genetic variant potentially could help to identify patients whose risk of developing TMD is heightened following orthodontic treatment, hence serving as a risk marker useful in planning orthodontic care.

MacFarlane, Kenealy and Kingdon (2009)[79] conducted a study to investigate the relationship between orthodontic treatment and TMD with a longitudinal study design.TMD prevalence was higher in females at all follow-up points, except the baseline. Overall, incidences of TMD were 11.9%, 11.5%, and 6.0% at the first, second, and last follow-ups, respectively. Females were more likely to develop TMD than males (hazard ratio [HR], 2.1; 95% CI, 1.3 and 3.3), and those with high self-esteem were less likely to develop TMD (HR, 0.6; 95% CI, 0.4 and 0.8). There was no association between orthodontic treatment and new TMD onset. The incidences of persistent TMD were 20.0%, 34.9%, and 28.0% at the first, second, and last follow-ups, respectively. Females were more likely to have persistent TMD than males (HR, 2.5; 95% CI, 1.0 and 6.1). There was no association between orthodontic treatment and persistent TMD. The only significant predictors of TMD in adults aged 30 to 31 were female sex (odd ratio, 3.0; 95% CI, 1.1 and 8.2) and TMD in adolescence (odds ratio, 4.5; 95% CI, 2.0 and 10.0).

CONCLUSIONS: Orthodontic treatment neither causes nor prevents TMD. Female sex and TMD in adolescence were the only predictors of TMD in young adulthood.

Hirsch (2009)[60] conducted a study to find out whether orthodontic therapy is a risk factor for temporomandibular disorders (TMD) or parafunctional habits such as bruxism is a question that has long been discussed. The issue is highly relevant to public health due to the frequency of these functional disorders in the general population and the sheer number of orthodontic treatments. The study revealed no increased risk of TMD in children and adolescents during orthodontic therapy, which seems to reduce parafunctional activities and thus the likelihood of noncarious dental damage.

- **Condyle and disc position:**

Pringle (1919)[102] was the first to recognize and describe the condition of disc displacement.

Ricketts (1969)[115] in a viewpoint article has described types of "improper occlusion" of which two are said to result in posterior displacement of the condyle.

Weinberg (1970)[145] concluded that bilateral asymmetric temporomandibular joint spaces are considered to be radiographic evidence of dysfunction, with rare exceptions. Unilateral or bilateral condylar retrusion is usually associated with disc derangement and *I* or palpable muscle spasm. In his sample of 67 patients, only 10 were asymptomatic, and these had concentrically positioned condyles.

Hoffman and Silverman (1973)[61] conducted a study to relate condylar position in centric relation and in centric occlusion in dentulous subjects. He found that 1) the condyle centers in a chin point guided CR average 0.28 mm posterior to their position in CO. 2) in this CR position, the condyles are sometimes superior to and sometimes inferior to their position in maximum intercuspation in about equal numbers. The further posterior the guided position is, the more likely the condyles are to be inferior, and the less posterior it is, the more likely they are superior. 3) Many displacement patterns were quite asymmetrical, exhibiting both AP torquing and S-I torquing of the mandible.) Some subjects CR's were slightly to the left and some were slightly to the right of their CO's.

Weinberg (1979)[146] concluded that condylar position in the fossa is a significant factor in TMJ dysfunction pain syndrome. Condylar retrusion occurs much more (71 %) than other types of displacement in acute TMJ dysfunction pain syndrome. Condylar retrusion also occurs with enough frequency in the control group to indicate that retruded mandibular position of centric relation does not necessarily orient the condyle correctly in the fossa. Condylar concentricity was 6.4 times more prevalent in the control group, this confirms that it is the optimum position in the glenoid fossa.

Sakuda and Tanne (1992)[128] constructed a three dimensional configuration of the **TMJ** by 108 triangles for the condyle and glenoid fossa. The shortest distance between the condyle and glenoid fossa was calculated **in** the model along a line perpendicular to the center of gravity of a triangle on the condyle. The condyle and glenoid fossa was determined in the anterior, posterior, middle, lateral and medial areas of the condyle. Preliminary investigations revealed that the technique was accurate, regardless of condylar rotations and inclinations to the tomographic table. This approach provided a method for evaluating the positional relationship between the mandibular condyle and glenoid fossa in patients with TMD.

Braun (1996)[16] studied a method of describing the geometric relationship of the condyle within the glenoid fossa on a sagittal cephalometric radiograph. Improved glenoid fossa and condyle visualization was achieved by adapting the Denar TMJ orthoceph Slimline cassette, which contains rare earth intensifying screens to enhance the TMJ. A plastic template was used to locate condyle ***I*** fossa relationship in habitual occlusion and it was found that 89% of the subjects exhibited noncentric condyle positions, while free of TMJ symptoms.

Tasaki and Westesson (1996)[137] developed a classification system for disk displacement in the TMJ and studied the prevalence of the various types of TMJ disk displacement in patients and symptom free volunteers. The study was based on bilateral MRls of 243 patients and 57 symptom free volunteers. Eight different types of disk displacement were identified in addition to the superior disk position and a tenth indeterminate category. Superior disk position was observed bilaterally in 18% of the patients and bilaterally in 70% of the symptom free volunteers.

Hickman and Cramer (1998)[57] evaluated twenty normal adults to determine masseter and temporal is activity in maximum static clench with mandibular condyles in different therapeutic positions. Bimanually manipulated, leaf gauge, centric occlusion and neuromuscular condylar positions were studied. Results showed that when mandibular condyles were placed anteroinferiorly in a neuromuscular position, total masticatory muscle recruitment was greatest. In a bimanually manipulated or a leaf gauge position, mandibular condyles were positioned superiorly, producing the least amount of muscle recruitment.

Crawford (1999)[23] conducted a study to determine if there is a relationship between condylar axis position as determined by the occlusion and signs and symptoms of TMD, using the condylar position indicator (CPI). A sample of subjects with ideal occlusions, defined as centric relation approximating centric occlusion, was compared with a control sample of untreated subjects. The comparison was based on written patient histories, clinical exams, and CPI measurements. The ideal sample of 30 subjects was selected from a population that had undergone full-mouth reconstruction using gnathologic principles that included centric relation (CR) being coincident with centric occlusion (CO). The control group consisted of 30 untreated subjects from the general population and was matched with the ideal sample with regard to sex. A duplicate written exam was given to the subjects in the ideal sample to assess symptoms prior to treatment. The CR bite registration technique developed by Roth was used. When the pre- and posttreatment examination scores of the ideal sample were compared, an 84% reduction in symptoms was found after treatment. A high correlation ($p<.001$) between signs and symptoms of TMD and CPI values was documented. Since condylar axis position is dictated upon closure of the dentition into maximum intercuspation and since condylar axis position was shown in this study to be strongly correlated with TMD symptomatology, it can be concluded that a statistically significant relationship exists between occlusion-dictated condylar position and symptoms of TMD.

Vasconcelos and Menezes (2007)[144] conducted a study in subjects who tested free of psychological stress to determine the position of the condyle and whether that position was related to signs and symptoms of temporomandibular disorders (TMDs).Forty subjects underwent psychological evaluation to ensure freedom from psychological stress. The authors evaluated tenderness of the masticatory muscles and temporomandibular joints (TMJs) by means of bimanual digital palpation, and they determined the positions of the condyle and disk by using magnetic resonance imaging.A total of 23.75 percent of the condyles were displaced away from the centric position either anteriorly (3.75 percent) or posteriorly (20.00 percent). chi(2) analysis showed a relationship between the position of the condyle and displacement of the disk, as well as a relationship between the position of the condyle and tenderness of the TMJs. Although these relationships proved significant, it cannot be assumed that displacement of the condyle away from the centric position is predictive of TMD.Only two subjects were judged to have had TMJ internal derangement. Thus, the absence of psychological stress seems to have played a role in this finding.

Robinson and Marques (2009)[118] conducted a study to assess the disk-condyle-fossa relationship through magnetic resonance imaging and determine its association with clinical signs and symptoms of temporomandibular disorder in patients with myofascial pain and disk displacement (with and without reduction).No significant association was found between the independent variables (condylar position, disk position, and condylar excursion) and the dependent variables (pain, maximal opening of the mouth, maximal lateral movement). However, there was a significant association between increased condyle excursion and pain (P = .035) and also maximum mouth opening movement was associated with lateral movement (P = .01; r = 0.31). Increase in condyle excursion may significantly influence pain perception in TMD patients. The type of dysfunction and severity of alterations on the imaging exams were not related to the severity of pain or range of motion of the mandible.

Maizlin ZV, and Nutiu N (2010)[162] evaluated whether MRI findings of various degrees of disk displacement could be correlated with the presence of clinical signs and symptoms in patients with a clinical disorder of the TMJ.

Concluded that Disk displacement on MRI correlated well with clinical symptoms in cases of significant disk displacement and in cases of disk displacement without reduction. When disk displacement with reduction was mild, there was no statistically significant difference between symptomatic and asymptomatic joints, which suggests that other causes should be considered.

- **<u>Methods of evaluating the TMJ:</u>**

Dawson (1971)[24] believes that if severe symptoms can be triggered by tooth interferences, which deviate the condyle position less than the thickness of thin cellophane, it is unrealistic to think that such minute deviations can be detected by any existing radiographic technique.

Mikhail (1979)[86] showed that **TMJ** radiographs made using the head positioner provided a valuable adjunct to diagnosis and treatment planning for patients with mandibular pain dysfunction syndrome (MPDS) syndrome. It was found that radiographic retrusion was more frequently accompanied by signs and symptoms than bilateral condyle symmetry and protrusion.

Franco Mongini (1981)[91] studied 8 men and 22 women with **TMJ** pain dysfunction syndrome. After clinical examination, transcranial radiographs (TR) and serial tomography were performed in 5 to 7 different planes. In 27 patients **TR** showed a condylar displacement. This was confirmed by serial tomography, which also showed that the apparent position might vary from the medial to the lateral aspect due to rotation in same patients.

Blaschke and Blaschke (1981)[12] investigated the condylar position in 25 symptomatic patients using corrected lateral tomograms. They found that mandibular condyles assumed widely varying positions within their respective joints when teeth were in centric occlusion. Some of the normal subjects presented joints in which the condyles could subjectively be classified as severely retruded or protruded.

Dixon et al (1984)[31] investigated the validity of transcranial radiographs in the diagnosis of anterior disc displacement in the TMJ. They examined 34 patients who had sufficiently severe symptoms to warrant arthrographic examination of one or both joints. Bilateral standardized transcranial radiographs were also obtained in the open, closed, and rest positions. The researchers found that transcranial radiographs were unreliable in predicting the presence of anterior disc displacement. The method was more valuable in correctly identifying disease free joints, but even then, the radiographs were not totally accurate.

Juniper (1994)[66] reported severe changes in condylar shape and size in the joints of 105 patients whose treatment involved arthrotomy for the surgical treatment of their TMD. Some of the changes reported would be hidden on standard radiographic views: 24% had medial bony excavaton, and 15% had lost part of their anterior surface and had an oblique shape. Admittedly, these patients may have suffered quite severe symptoms, but this work does indicate what may be invisible on plain radiographic films.

Reef and Pancherz (1995)[110] in a dried skull study investigating the use of orthopantomography for TMD diagnosis questioned the reliability of such radiographs for TMD diagnosis. They reported simulation of condylar flattening, osteophytes, joint space narrowing, and similar artifacts due to changes in skull positions.

Ramfjord and Ash (1995)[108] believe that TMJ radiographs are useful for differential diagnosis but are valueless in diagnosis and treatment of TMJ dysfunction.

Emshoff and Bertram (1997)[35] investigated the value of ultrasonography to determine the TMJ disc position in 17 patients. 100 TMJ positions were studied by static and dynamic ultrasonography to analyze the disk- condyle relationship. To compare the respective findings with those of a diagnostic method offering high accuracy, coronal and sagittal magnetic resonance imaging was carried out immediately afterwards. Results revealed that static and dynamic ultrasonography are marginal in detecting the presence of disk displacement, but dynamic ultrasonography is sensitive in detecting the absence of disk displacement. The results indicate that both modalities are insufficient in establishing a correct diagnosis for the presence or absence of disk displacement.

Landes and Walendzik (2000)[72] conducted a study in which sonographic examination was compared with MRI and axiography in assessing temporomandibular joint (TMJ) function in 55 patients. Fifty-five patients with different TMJ problems were examined clinically, by means of axiography, sonography and some also by MRI. The range of motion was measured by sonography and axiography and the results compared using Student's t-test. Anatomical details diagnostic for disc-displacement were tested by sonography and MRI.The average time required for sonography was 2 min and for axiography 20 min. The mean measurement differences for condylar movement in maximal mouth opening was 1.7 mm, for protrusion 1.6 mm and for mediotrusion 2.5 mm. The range of condylar movement as measured by sonography and axiography coincided for opening and for protrusion (statistically significant). No significance was found for lateral excursions. The concordance in diagnosis of disc dislocation, hypermobility and impaired range of motion when comparing ultrasound with MRI was 83%. All sonographic examinations were performed by one person only. Sixty repeat examinations in patients produced no complaints and showed an absolute range of difference of 0.6 mm, with a relative range of 7%. Student's t-test was significant ($p<0.05$) (two repetitive measurements). Sonography proved to be a fast and reliable method for evaluating the range of movement of the TMJ. The lateral joint capsule, lateral disc, and upper condyle could be demonstrated. Pathological processes such as anterior or lateral disc displacement, disc perforation, seroma following contusion, capsular fibrosis, crystalline structures in the synovia and fracture dislocation of the condyle could be diagnosed with considerable reliability when compared with MRI. However, the medial aspect of the joint, medial disc dislocation and the angulation of the condylar slope could not be seen.

Gomi and Yokoi (2007)[54] conducted a study to evaluate the potential clinical application of digital linear tomosynthesis systems in imaging of the temporomandibular joint (TMJ).A volumetric X-ray digital linear tomosynthesis system (Sonialvision Safire; Shimadzu Co., Kyoto, Japan) was used for TMJ imaging. Images were reconstructed with a modified three-dimensional (3D) filtered backprojection (FBP) algorithm on this device. Our modified 3D FBP was first evaluated using simulated images of numerical phantoms. Next, patients with TMJ disease were evaluated with X-ray digital linear tomosynthesis. The results indicate that numerical phantom and TMJ visualization can be improved by the ability to produce sectional images that blur overlying structures and yield 3D information. The flexibility of digital linear tomosynthesis, as well as the fact that through an appropriate choice of modified FBP algorithms it can suppress streak artefacts, makes it a potentially appropriate approach for evaluating the TMJ. The utility of digital linear tomosynthesis for the evaluation of TMJ was demonstrated. Digital linear tomosynthesis may be considered as the imaging technique of choice in the investigation of bony changes of the TMJ.

Ottl and Hardenacke (2008)[96] conducted a retrospective study to systematically assess the temporomandibular joint (TMJ) using a newly developed standardized evaluation form with 16 parameters based on MRI diagnostics and to verify the reliability of the MRI diagnoses. One hundred fifty-four (154) TMJs of 77 patients with arthrogenic complaints were evaluated using MRI on two planes (parasagittal, paracoronal), in both closed-mouth and open-mouth positions. The sequences used were intermediary FLASH and spin echo sequences using T1 or T2 weighting with fat suppression. Examination of the reliability of the MRI evaluations of three independent observers evaluating 60 randomly selected TMJ from among the overall sample using the new evaluation form yielded an average Pearson contingency coefficient of between 0.64 and 0.70 with regard to the 16 parameters studied. In the evaluation of the 77 left (L) and 77 right (R) joints, the biplanar morphology of the disk was the most frequent with 24.7% (L) and 32.5% (R). In paracoronal projection, medial displacement of the disk was seen in 7.9% (L, R) of the cases and lateral displacement in 6.4% (L) and 3.2% (R). The use of the new evaluation form, in combination with MRI of the TMJ, demonstrated a substantial reliability of the diagnoses. In TMD patients, the biconcave disk shape cannot be considered the sole normal, standard situation. The presence of lateral and medial disk displacement should be given more diagnostic consideration.

Guarda and Manfredini (2009)[44] studied the use of hyaluronic acid in temporomandibular joints with inflammatory/degenerative processes. This investigation aimed at evaluating retrospectively the efficacy of intra-articular injections of hyaluronic acid in elderly patients (aged >65 years) with osteoarthritis of the temporomandibular joint as compared with those of a group of adult non-elderly patients.At the end of the treatment period, improvements in the elderly group were significant with respect to baseline values in the minimum and maximum masticatory pain, maximum pain at rest values, and functional limitation scores. In the non-elderly group, significant improvements at the end of treatment were showed in all treatment outcome variables, except than minimum pain at rest values. All improvements were maintained over the six-month span of the follow-up period, and no significant differences were showed between groups for any of the outcome variables, except than functional limitation scores, which improved more in the elderly group.These findings are not supportive for a difference in efficacy between the elderly patients and the other subjects, even though further works on different age groups are needed before generalization of results.

ZK Ahlers and Jakstat HA (2010)[161] describes Computer-aided examination reports in clinical functional analysis of TMD. Clinical functional analysis is the first step in the diagnostic cascade in the diagnosis of craniomandibular dysfunction (CMD). This examination comprises palpation of the muscles, auscultation of noises in the temporomandibular joint, registration of jaw mobility as well as the search for dysfunctional contact relations in static and dynamic occlusion. The structured evaluation of these findings enables an initial diagnosis to be made as the basis for further diagnostics and therapy. Because of the complexity of the material, both the referring dentists and the patients expect a meaningful examination report. However, writing it is extremely time-consuming. New software for the semi-automatic generation of such illustrated medical reports has therefore been developed to reduce internal costs and provide quality assurance. The CMD medical report assistant (dentaConcept) imports the examination data and initial diagnoses through a standardized interface from the dentaConcept diagnostic software CMDfact. The CMD medical report assistant assigns matching texts to the findings on the basis of random number generators and combines these findings-dependent texts with illustrations of the most important findings as well as standard texts. The software transfers the multi-page examination report to the standard Microsoft Word for Windows word processing program, saves the data by means of an individualizable file name generator and uses the Word functions for the color printout.

- **Recording maxillomandibular relations:**

Long (1973)[75] was the first to introduce the leaf gauge in 1973. It consists of a number of shims usually made from acetate or plastic such as exposed radiographic film cut into 1 by 5 em. pieces. These are then connected at one end by means of a staple. Use of the leaf gauge is made by adding individual leaves between maxillary and mandibular incisors and instructing the patient to "bite on the back teeth, both sides at the same time". If any posterior teeth begin to touch another leaf is added and the instructions to the patient are repeated. When the patient is able to close on the leaf gauge for approximately five minutes without posterior tooth contact, the mandibular condyles are considered to be in a muscle dictated CR. Condyles are positioned by the patients own muscular force, and not by the operator. The leaf gauge permits this accomplishment without any tooth contact influencing the muscles to position the jaw at maximum intercuspation position. Muscle patterns have been shown to be affected by aberrant tooth contact or deflections.

Williamson et al (1978)[149] used the "centric ceph" technique on a sample of 46 patients divided into groups of Angle Class I and Angle Class II cases. They concluded that there were differences in cephalometric measurements with respect to the mandibular position, though most differences were slight. They found that Class II patients exhibited the largest discrepancies.

Williamson (1980)[150] used the" veri check" to analyze the variability of CR records or to compare mandibular condyle position in the glenoid fossa by using different types of interocclusal records. The Vericheck instrument offers one method of testing sequential records for reproducibility. It resembles an articulator in that models previously mounted by means of a face bow recording and CR interocclusal records may be transferred to the vericheck simply by attaching them to the upper and lower members by means of the mounting plates.

Slavicek (1988)[130] described the use of the SAM articulator with the MPI to quantify differences between the joint dominated recorded condylar position and the tooth dominated position of maximum intercuspal position. The MPI is an instrument that allows the clinician or researcher to evaluate the magnitude and directional displacement that occurs in the condylar axis from CR to CO. The nature of the slide at the level of the occlusion most often does not necessarily reflect the condylar movement. The MPI is a modified upper member of the SAM2 articulator in which the condylar housings have been replaced with laterally sliding cubes that contact the medial poles of the condylar elements when related to the lower member of the articulator.

Yasuo and Kolling (1989)[157] described a method in which mandibular border movements of a subject can be compared with the movements generated by various articulators (fully adjustable Denar and semiadjustable Denar) by using an electronic pantograph. Pantronic pantograph detected differences between human border movements and those generated by each articulator and method of adjusting it. In the horizontal table, the semiadjustable articulator without immediate side shift always showed the potential of greatest errors, especially as excursions started. When the semiadjustable instrument was programmed with immediate side shift, its movements were comparable with the fully adjustable articulator. Neither articulator exactly simulated the subject's movements.

Wood (1994)[154] studied "centrically related cephalometrics" with a sample of 30 patients whose casts were mounted on a whip mix articulator (using Face bow at centric bite) His "shadowgraph technique permitted the comparison between CO and CR. Limitations due to the radiographic enlargement factor allowed the measurement of only a small number of cephalometric angles. Wood stated that "although the statistical analysis suggests the accuracy of the shadowgraph, it by no means renders the technique clinically applicable". He did however conclude that mounted casts and centrically related cephalometries offer more accurate information than hand held casts.

Klar and Kulbersh (2003)[93] conducted a study to examine the condylar position indicator (CPI, Panadent Corp, Grand Terrace, CA) readings of 200 consecutively finished patients in a gnathologically oriented practice to determine the nature of the centric relation (CR)-maximum intercuspation (MI) discrepancy pretreatment and posttreatment, in extraction and nonextraction cases as well as to examine the possible effect of skeletal morphologic parameters on treatment outcome. The study consisted of 200 patients, 127 women and 73 men, whose average age was 14 years and 2 months and ranged from 9 years to 55 years old. These patients were treated using the Roth gnathologic treatment philosophy and straight-wire appliance. Finished cases were defined as patients who completed treatment with a gnathologic positioner. Initial records included upper and lower alginate impressions, an estimated face-bow transfer, a maximum Intercuspation wax bite using Moyco 10× pink wax (Moyco Industries Inc, Philadelphia, PA) and a preliminary 2-piece Roth power centric CR bite registration using Delar blue wax (Delar Corp, Lake Oswego, Or.). CPI measurements were made on all casts, pretreatment and posttreatment, to record the positional changes of the condylar axes from MI to CR in all 3 planes of space. The measurements were made to the nearest 0.1 of a millimeter with the Panadent optical resolver. A mixed-design analysis of variance was employed using pre- and posttreatment values as the within-subjects factor and skeletal Class, vertical growth pattern as assessed by upper/lower face height ratio values, and extraction or nonextraction as the between-subjects factor. All groups responded to treatment with a statistically significant reduction in MI-CR discrepancy in all 3 planes of space-x, y, and transverse—between pretreatment and posttreatment records.

STUDY OUTLINE

30 Patients were selected based on the inclusion criteria of the study (15 Extraction and 15 Non- Extraction)

Records

- Impression
- Study models
- CR Bite
- MI Bite
- Facebow transfer
- Intraoral photographs

Study models were mounted on SAM2 Articulator using SAM Anatomic Facebow and CR Bite

MPI readings were taken and tabulated

Statistical analysis was done from the values obtained from MPI readings

Extraction Group
N = 15

Non – Extraction Group
N = 15

Non- Extraction
+
Extraction Group
N = 30

Results

MATERIALS AND METHODS

The study group consisted of 30 subjects with the following criteria.

1. All of them treated by post-graduate students in the Department of Orthodontics, Ragas Dental College, Chennai.
2. These subjects, 18 females and 12 males ranged in age from 14 yrs to 25 yrs.
3. None of them had any relevant medical history.
4. Both extraction and non-extraction cases were included.
5. No temporomandibular joint signs or symptoms were present before treatment.
6. All of them were treated using .022 Roth Ovation brackets with atleast 6 months in retention.

Methods:

1. Impressions were taken using Alginate impression material and poured using hard dental stone.

2. The models were trimmed and all air bubbles removed from the surface.

3. The facebow records were taken on each patient using the SAM (Great Lakes orthodontics, NY, USA.) anatomic facebow system.

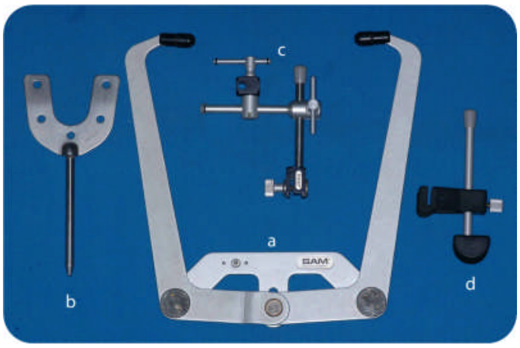
The components of the SAM System facebow are as follows:

a) Facebow

b) Bite fork

c) Bite fork stem assembly

d) Nasion relator



The elements that make up the facebow are as follows:

a) Two lateral arms (1)

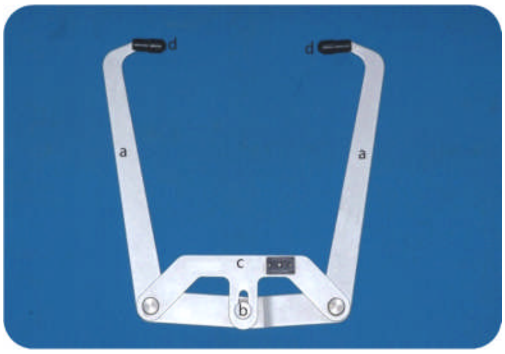
b) Central screw (2) that joins both lateral arms & allows change in width

c) Cross bar (1 a) designed to:

   1) Position the nasion relator (3a)

   2) Positon the bite fork stem (3b)

d) External ear pieces (4)



4. Steps for facebow recording**.**

- **Step 1**

The bite fork with the green stick compound was placed in a water bath at 60°C (140°F) until it softened.

- **Step 2**

After the compound was shaped, it was run under cold water before it was put in the mouth. This cooled the bitefork and caused the base of the compound to become more firm. This helped to prevent overseating of the bitefork touching the teeth. It also helped to overcome any discomfort for the patient due to the overheated bitefork.

- **Step 3**

The bite fork was placed in the patient’s mouth aligning the center mark with the facial mid line. It was lightly pressed towards the teeth. Indents were made in the compound making sure that no teeth came in contact with the bitefork. The bite fork was then removed and cooled in ice water.

- **Step 4**

With a scalpel all the excess compound was eliminated until the indentation was only 1 mm deep. It was made sure that only cusp tip indexing was seen without any undercuts.

- **Step 5**

The bite fork was placed in the mouth to check that the mid-lines coincide and that it was stable and that no teeth touched the bitefork.

- **Step 6**

The nasion relator was placed on the facebow cross bar.

- **Step 7**

Attaching the Bite fork stem assembly to facebow:

At the top of the transfer fork assembly, there is a black portion with a dovetail slot. On the underside of the facebow, there is a black dovetail slide. The transfer fork assembly is attached to the facebow by guiding the dovetail slot onto the dovetail slide. The assembly will be secured once it contacts the small silver pin at the end of the slide. The screw was tightened

- **Step 8**

The lateral arms of the facebow were then separated and placed in the patient's external auditory canal. The patient was then instructed to hold the facebow in that position while the central screw was tightened to lock the width of the facebow.

- **Step 9**

While the patient was still holding the facebow arms, the nasion relator was placed on the patient's nasion. Using the nasion relator like a plunger, gentle pressure was applied to push the relator against the patient. This moved the earpieces more forward to approximate the condyles.

- **Step 10**

The facebow should be standing on its own, parallel to the Frankfort plane. While in this position, the patient was requested to open his/her mouth so as to place. The bitefork and the transfer piece together .with all the fixation components loose, to allow free movement of all components.

- **Step 11**

The operator should be facing all fixation elements when placing them. Fix the transfer piece to the facebow and reposition the bitefork by using the occlusal imprints as a guide.

- **Step 12**

After positioning the transfer piece, all components should be at right angles to each other. Adjust and tighten elements and remove the piece from the mouth. The facebow should bear the weight of the transfer piece and of the already adjusted bitefork, which should not slide downwards when released.

- **Step 13**

The facebow was disassembled by loosening the central screw and removal of the nasal stabilizing device was done.

5. The Maximum Intercuspation (MI) bite was taken using beauty pink wax of Great Lakes Corporation (Fig.8) (Fig. 12 a,b & c).

The wax was approximately trimmed to fit the occlusal table of the upper model. It was then heated using a water bath maintained at 138° F. It was then placed in the patients' mouth and the patient was asked to bite into the wax in habitual occlusion. The wax bite wax taken out and chilled with ice cubes.

6. Each subject was placed on cotton rolls between the incisors for a minimum of 5 minutes before taking the Centric Relation (CR) bite to deprogram any occlusion generated mandibular deflective movements.

7. A Centric Relation (CR) was registered for each patient using the Roth Power Centric 2-part Delar blue wax (Fig.8) (Fig.11a, b & c). (F)The anterior segment consisted of three-layer thickness Delar blue wax based on the overjet, overbite and width of the anterior segment. The posterior section was of two-layer thickness involving the first permanent molar and second bicuspid tooth.

The anterior wax was heated in a water bath maintained at 138^{O} F and placed in the patients' mouth registering from cuspid and incisor area. The operator guided the patients' mandible into Centric Relation (CR) by supporting the condyles upward and guiding downward at the chin. The anterior segment was cooled with ice cubes.

The posterior bite was taken with the mandible guided to close in the same manner into the hardened anterior segment. This allowed the patients' musculature, to aid in seating the condyle. Both the bites were subsequently removed and the posterior portion was now chilled with ice cubes and checked for accuracy.

8. Articulation:

Mounting the upper cast is a lab procedure that uses the bite-fork assembly with the facebow for each patient and transfers the maxilla's spacial position to the upper member of the articulator.

The following materials were necessary for mounting the upper cast:

1) Articulator (Fig.4)
2) Upper cast
3) Mounting plate (Fig.9)
4) Facebow (Fig.5a & b)
5) Mounting Jig (Fig.6)
6) Fast setting plaster

Steps for upper cast mounting.

Maxillary cast was transferred to the articulator with the face bow. The bite fork, in the mounting jig was supported on a sliding rod with wheels on either side so that the weight of the cast will not alter the transfer position (Fig. 13a). The upper cast was placed into the impression on the bite fork and was connected to the upper part of the articulator with dental plaster (Fig. 13b)

The cast was thus mounted in a position corresponding to that of the upper teeth in the patient's skull.

Steps for mounting the lower cast.

The incisal pin was fixed at -6mm. The Bennett angle was set at 5 degrees to seat the articulator condyles and the Condylar housing was set at 30 degrees (manufacturer's specifications due to difference in articulator hinge axis and maxillary pin on the condylar box). The interocclusal record was placed between the casts and firmly held until the mandibular cast was mounted to the lower member of the articulator (Fig. 13c). After the mandibular cast was mounted, the hinge axes of the articulator's condylar spheres duplicate the hinge axes of the osseous condyles and the incisal pin position was set to the point of initial tooth contact.

Assessment of condylar position:

STEPS (Fig. 14a to 14f)

A. The maxillary cast was mounted with the SAM2 Anatomical Transfer Facebow and then the mandibular cast was mounted with a Centric Interocclusal Record.
B. The incisal table on the lower member of the articulator and the incisal pin assembly on the upper member were placed.
C. Calibrate the gauge was calibrated to zero.

(1) The articulator was locked in centric gently with centric locking screws. Close to first contact and the incisal pin was raised.

(2) The incisal graph paper was attached to the incisal table and red marking tape was placed on top of the graph paper with the marking side down. The incisal pin was moved down to contact the paper and a mark on the graph was obtained.

(3) The height value of the incisal pin was read and the value was entered on the MPI record form.

(4) The upper member of the articulator was removed and the maxillary cast was transferred to the mandibular position indicator (MPI).

(5) The MPI was prepared by inserting the incisal pin halfway.

(6) The condylar graphs were placed parallel to the edges of the cubes and use the articulator symbols on the graph was used as a guide for right and left.

(7) The maxillary cast was postioned into the most completely interdigitated position by using CO bite and was holded securely against the mandibular cast.

(8) Black marking tape on top of the graph paper on the incisal table was placed. Carefully The incisal pins was lowered, the incisal pin then taped once and locked. The height value of the incisal pin was read and the value was entered on the MPI record form under.

(9) The MPI assembly was firmly holded in position and Black marking tape was placed between the sliding cube and condylar element with the marking side towards the cube. The cube was moved and taped against the condylar element to obtain a recording of the CO position in the horizontal (X) and vertical (Z) position. The procedure was repeated for the opposite side.

(10) To measure transverse displacement of the mandible, the gauge arm was swinged down into the slot in the left sliding block. Readings in black on the gauge indicate the mandible is shifted to the left. Readings in red indicate a shift to the right. The small dial registers in mm; the large dial registers in tenths of millimetres

The transverse displacement of the mandible is measured and is identified as the Y axis and is the lateral movement of the black cubes. There is 5 mm of space between the inner wall of the black cubes and the MPI frame. Since the distance is equal on both sides, it is only necessary to measure one side and determine whether it moves medially or laterally. The left side is measured and identified with positive for lateral movement and negative for medial movement.

(11) The recording graph were removed from the incisal table and from the cubes and were placed on the examination form. The perforated centric points were highlighted with a fine point red pen.

(12) The horizontal displacement (X axis) value were entered under Delta X, and the vertical displacement (Z axis) velue were entered under Delta Z on the examination form. The value for the vertical incisal pin difference were entered as Delta "H" on the examination form. the incisal pin difference registered on the incisal graph was entered as Delta “ L “on the examination form. Only the Delta "H" and Delta "L:' values recorded on the incisal table were used. The lateral deviation is of no value.

Fig. 1: Patient’s Intraoral photographs

Fig. 2: Patient's Intraoral photographs

Fig. 3a : Conventional Study Model

Fig. 3b : Mounted Study Cast

Fig. 3c : Conventional Study Model

Fig. 3d : Mounted Study Cast

Fig. 3e : Conventional Study Model

Fig. 3f : Mounted Study Cast

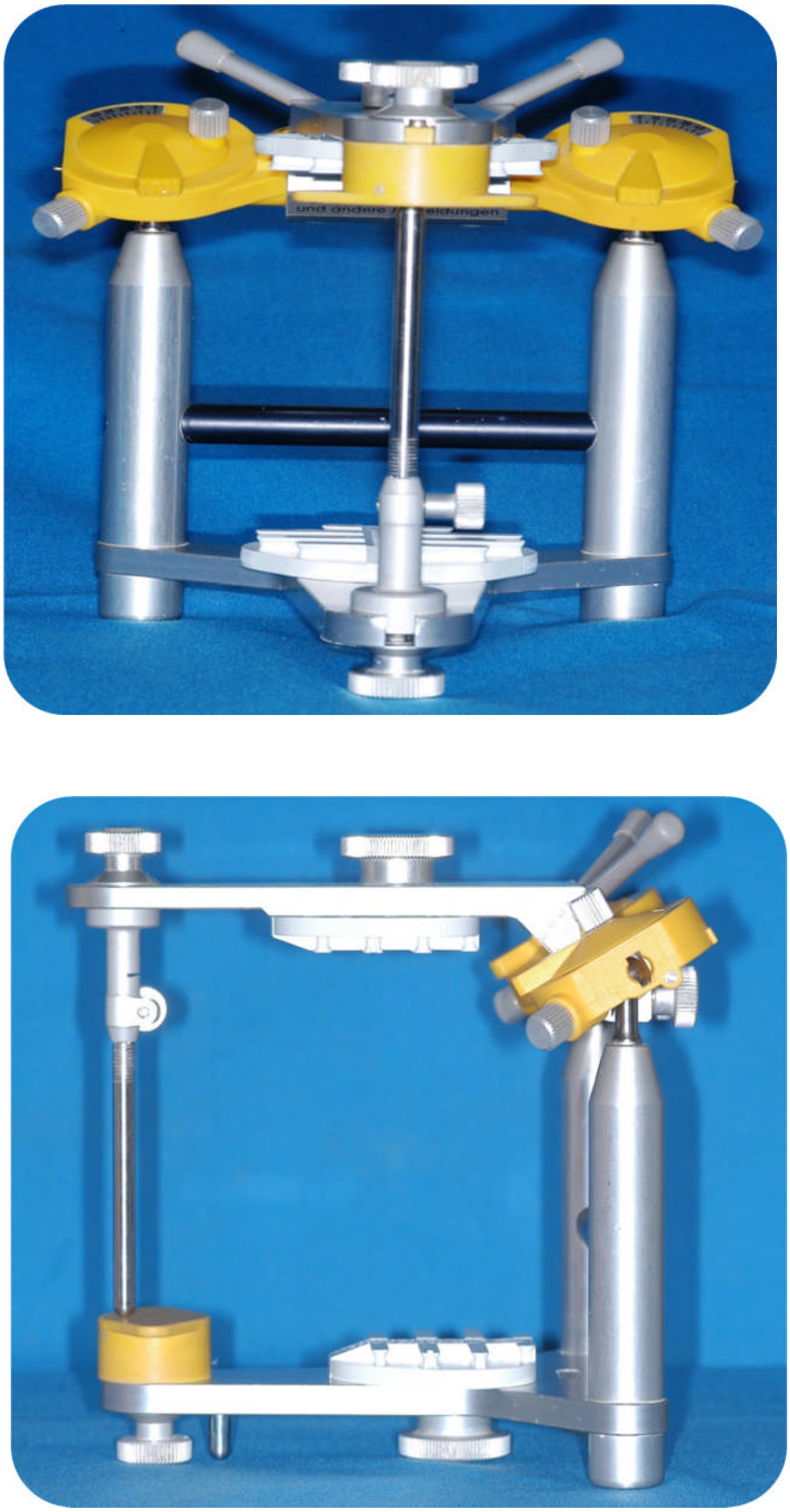


Fig. 4 SAM2 Articulator

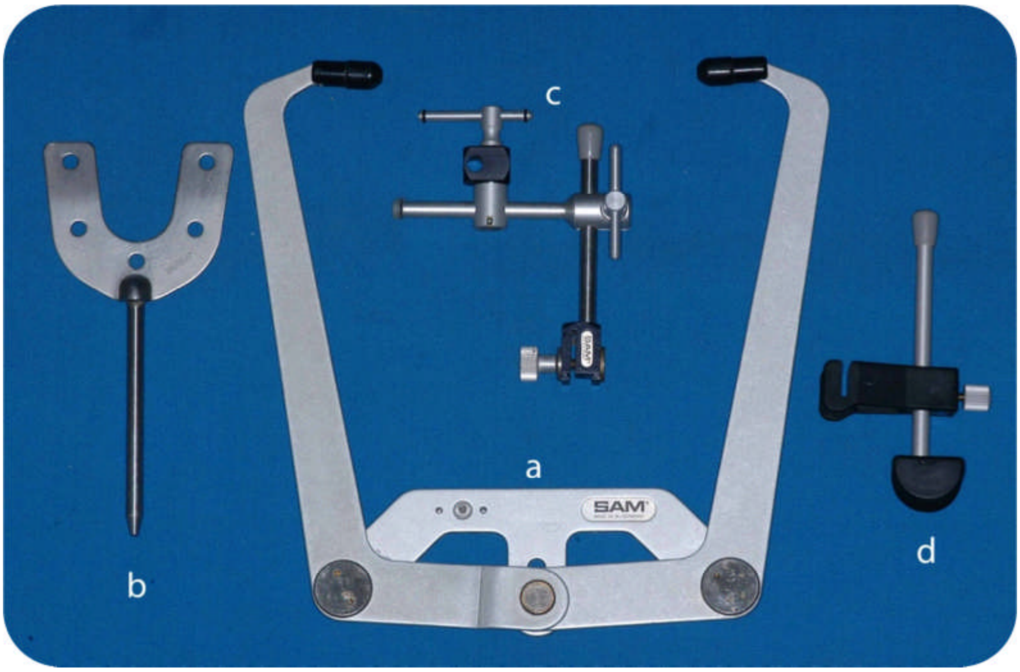


Fig. 5a :SAM Anatomic Facebow

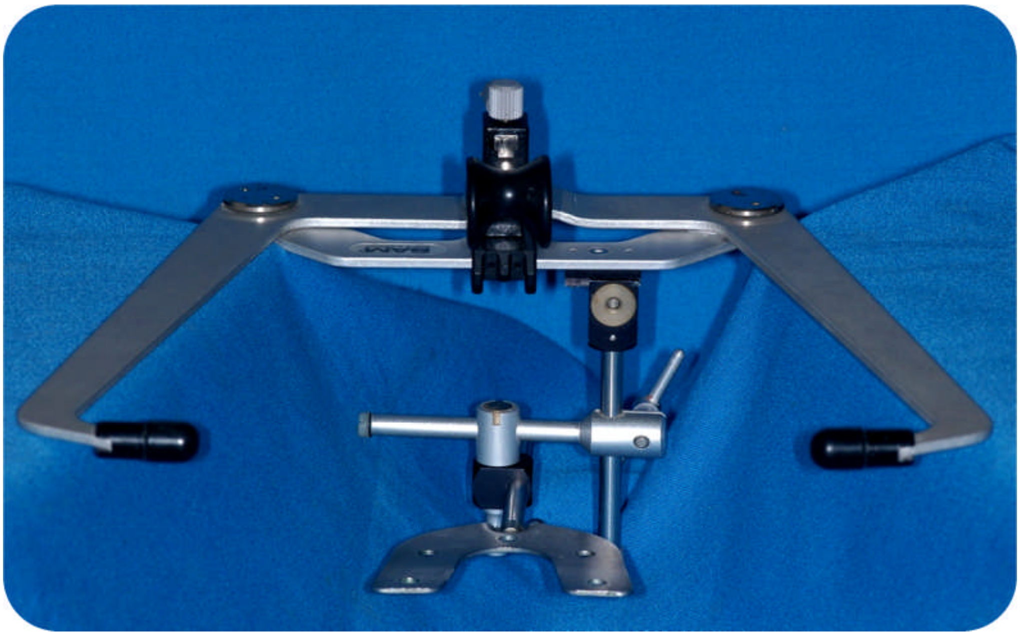


Fig.5b : SAM Anatomic Facebow

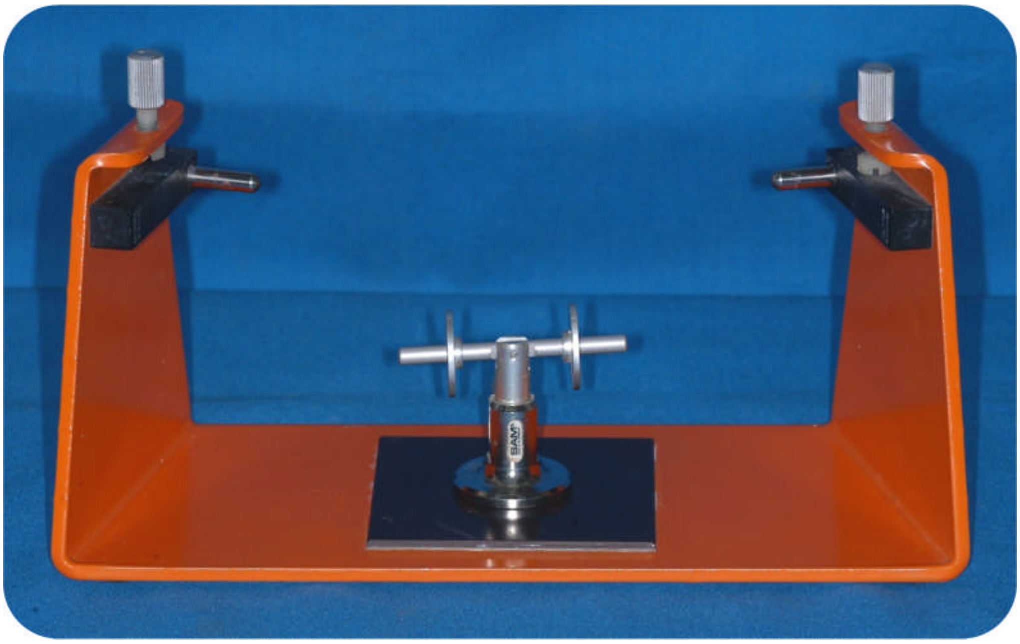


Fig. 6 : Mounting Jig

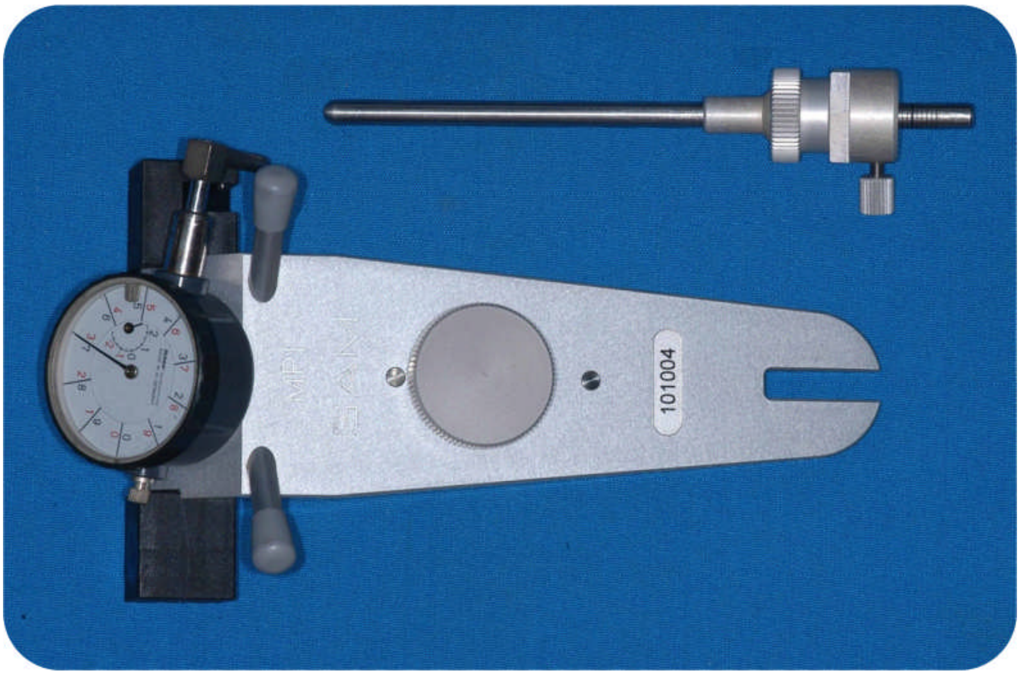


Fig. 7 : Mandibular Position Indicator

Fig. 8:Bite Registration Wax

Fig. 9 : Mounting Plates

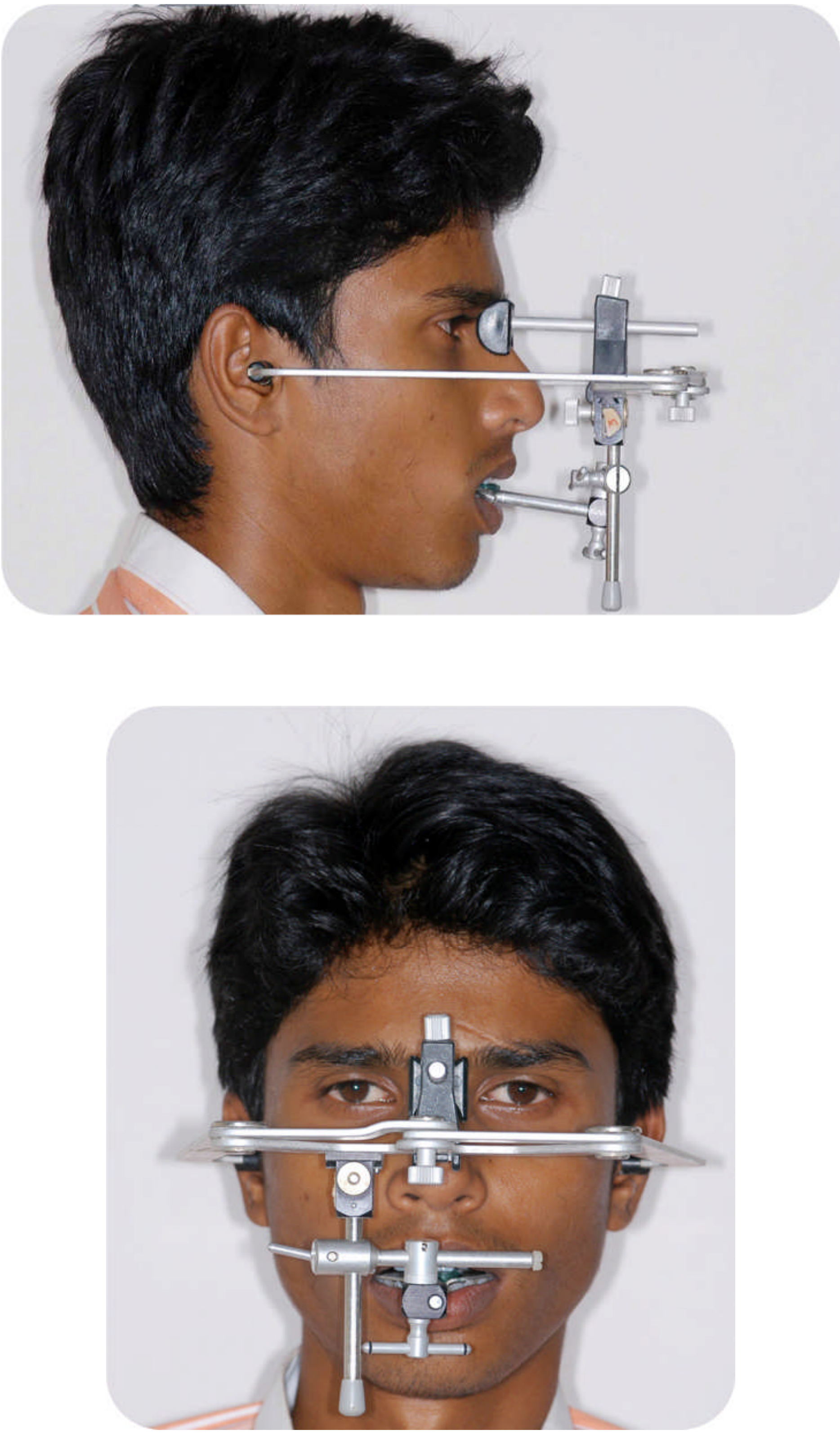


Fig. 10 : Facebow Transfer

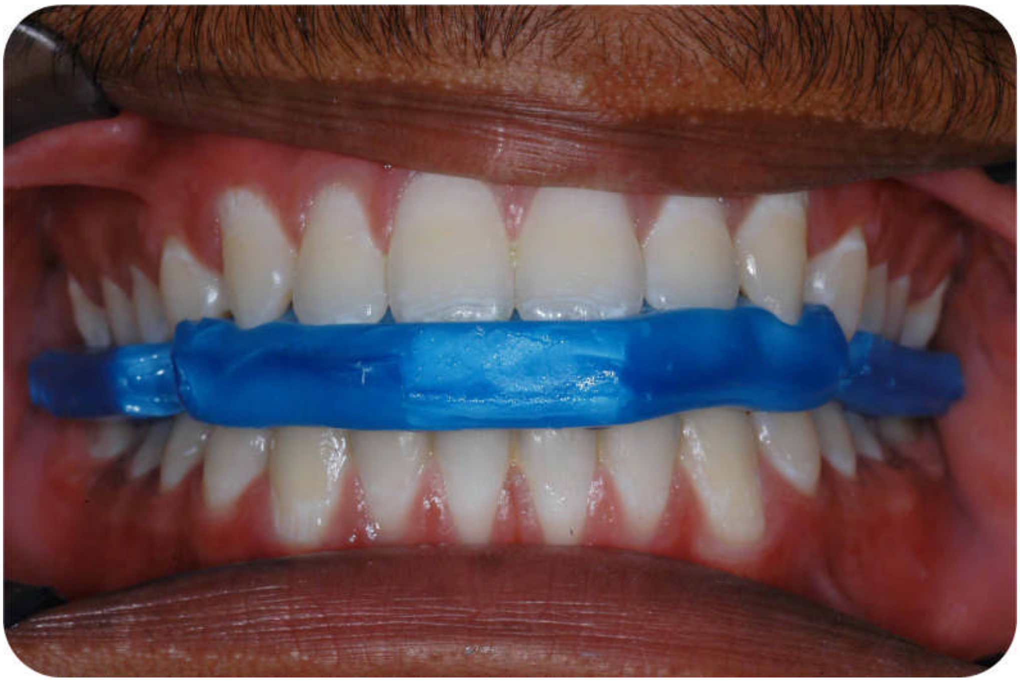


Fig. 11a : ‘Power Centric ’ wax interocclusal registrations

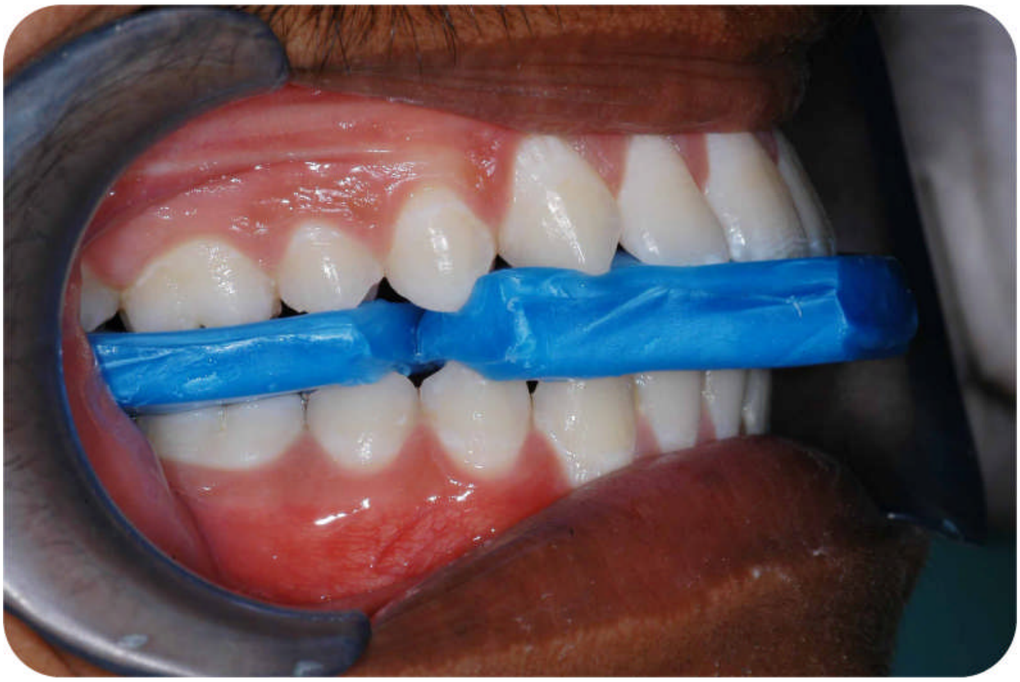


Fig. 11b : ‘Power Centric ’ wax interocclusal registrations

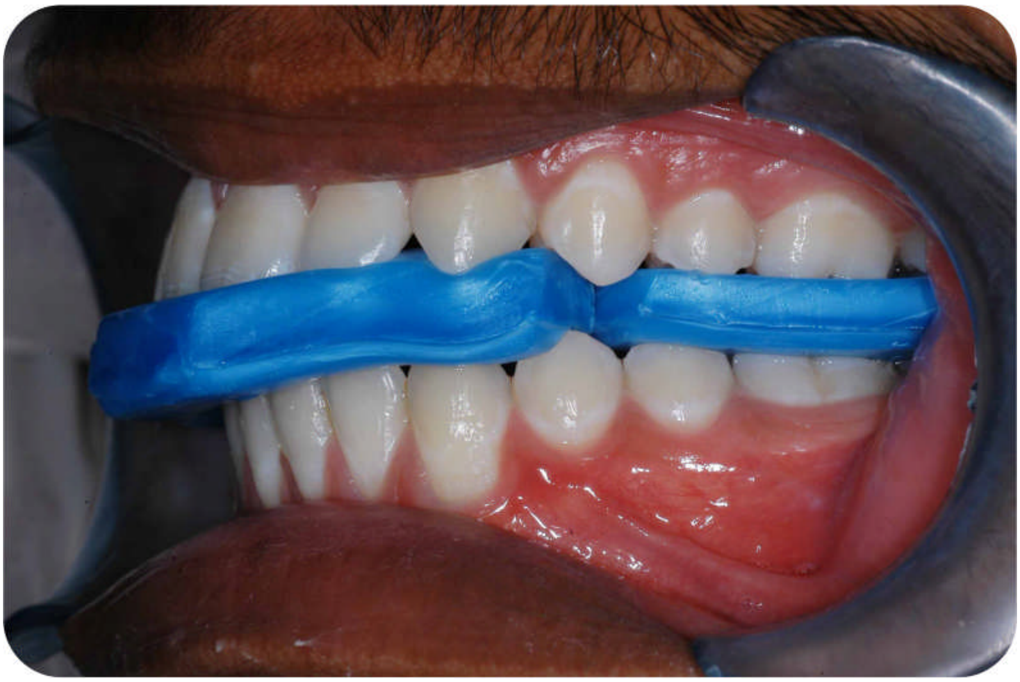


Fig. 11c: ‘Power Centric ’ wax interocclusal registrations

Fig. 12a : MI Bite registrations

Fig. 12b : MI Bite registrations

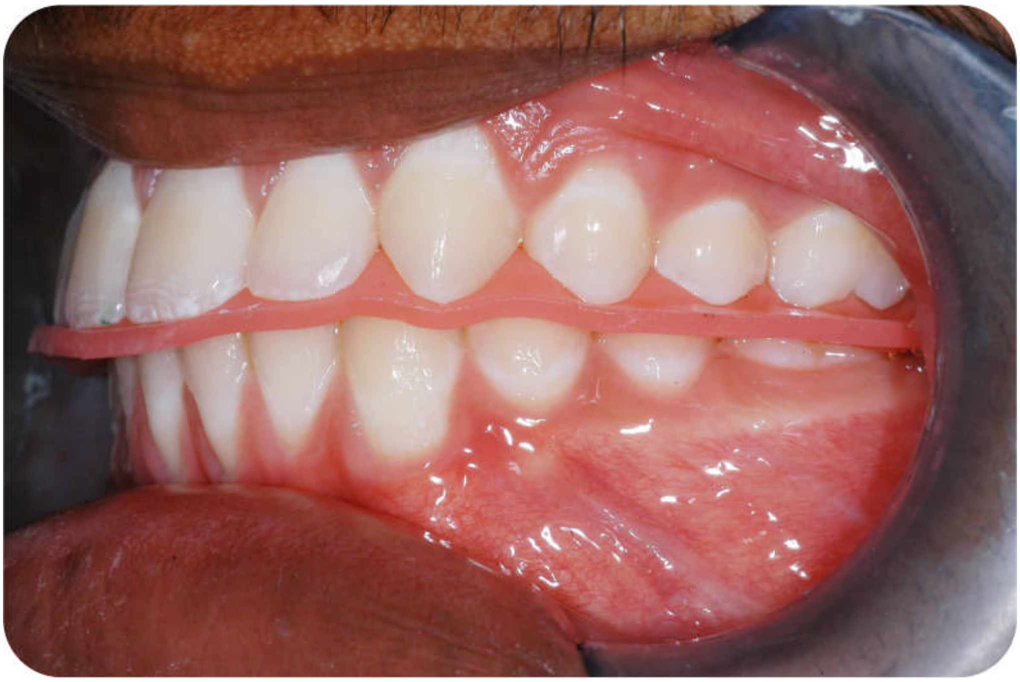


Fig. 12c : MI Bite registrations

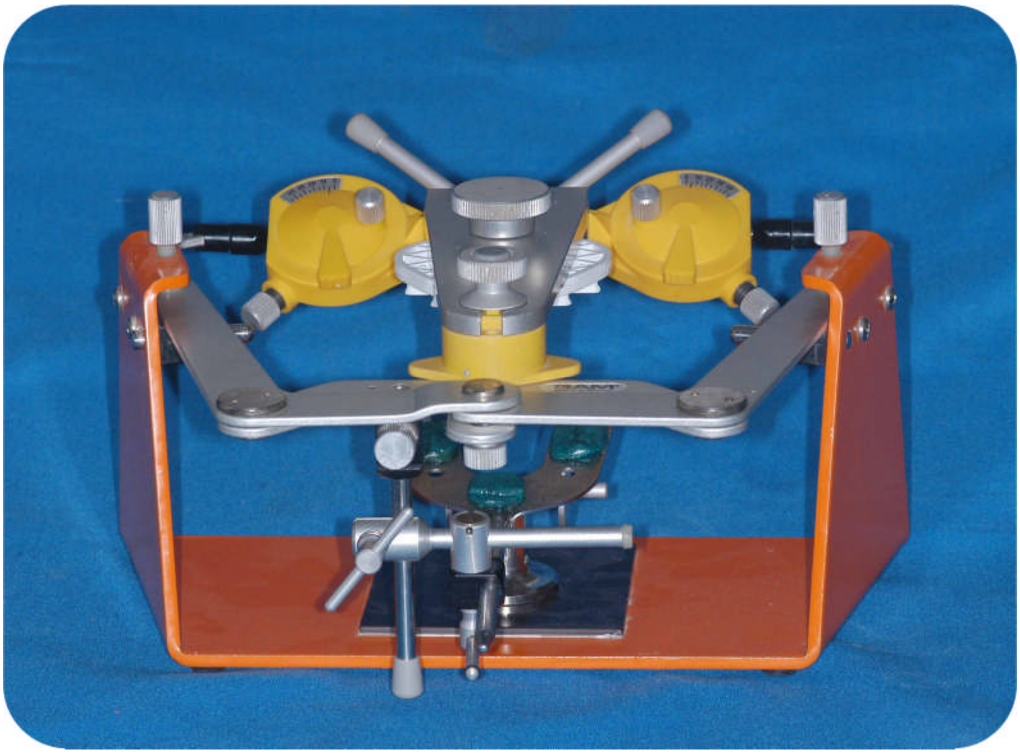


Fig. 13a: Facebow and mounting jig with upper member of the articulator

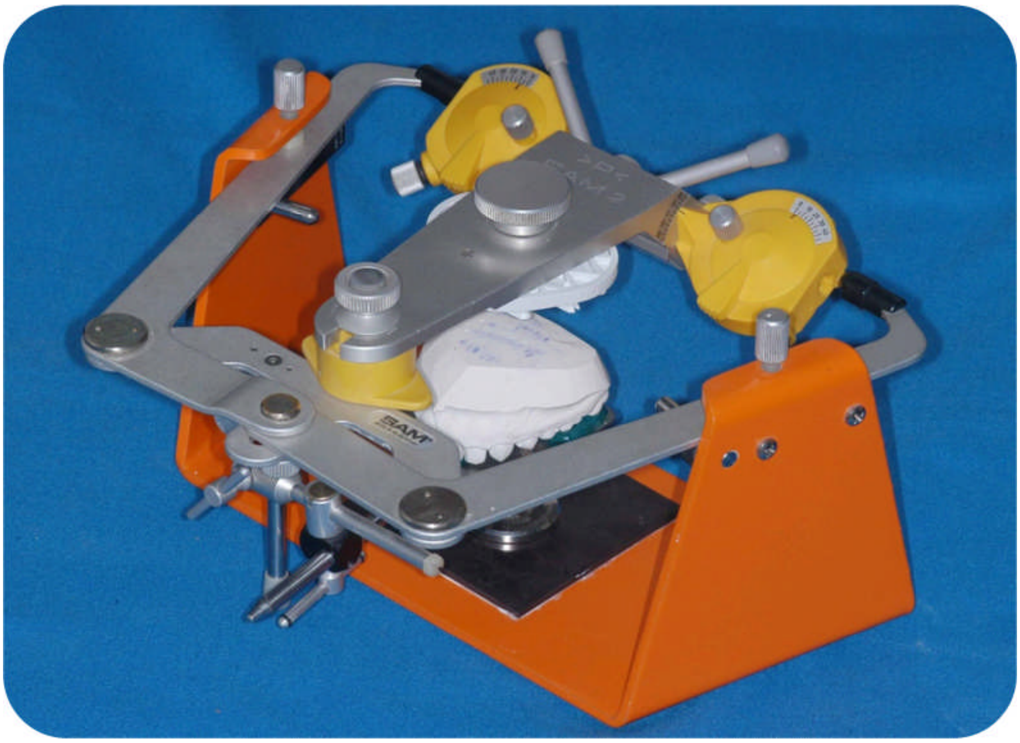


Fig. 13b : Maxillary cast transferred to the articulator

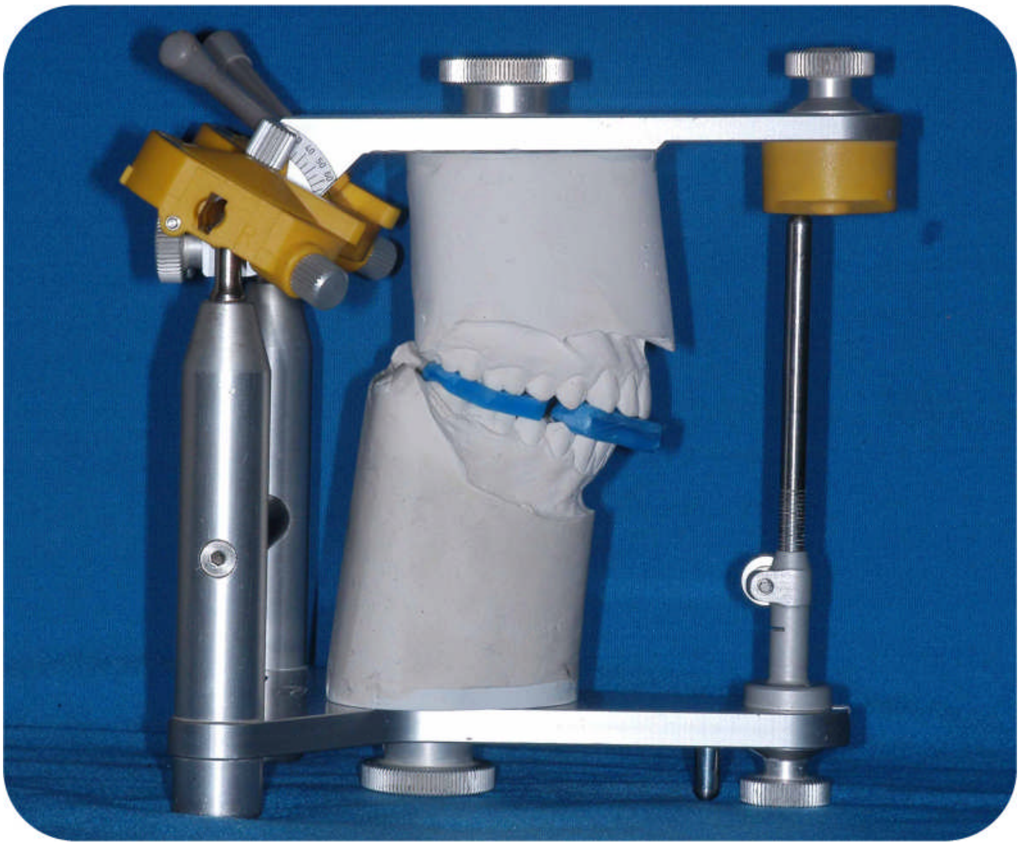


Fig.13c : Mandibular cast mounted on the SAM2 articulator with CR bite record firmly placed in between the cast

STEPS INVOLVED IN MPI READING

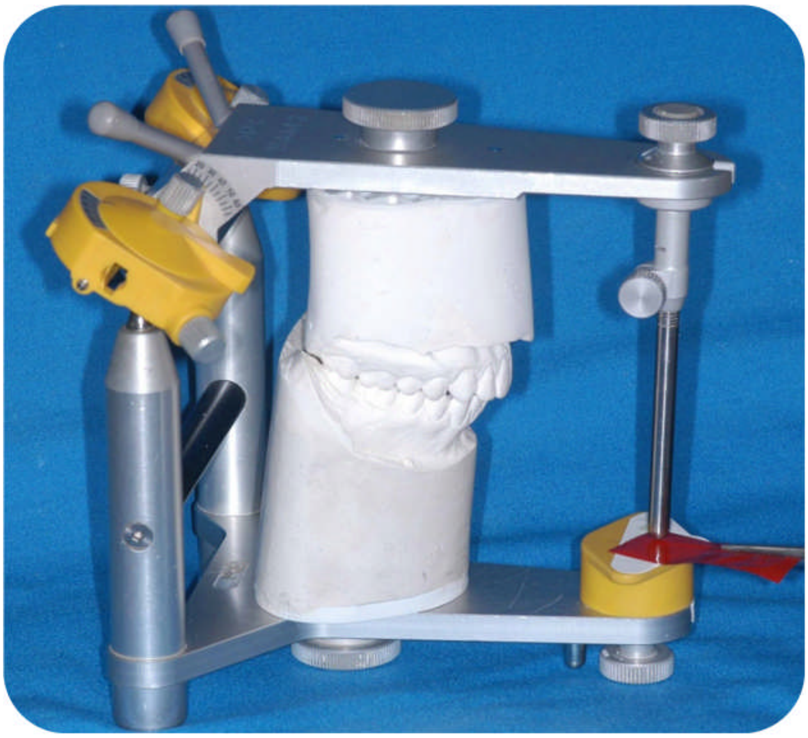


Fig .14a : Step 1 , 2 & 3

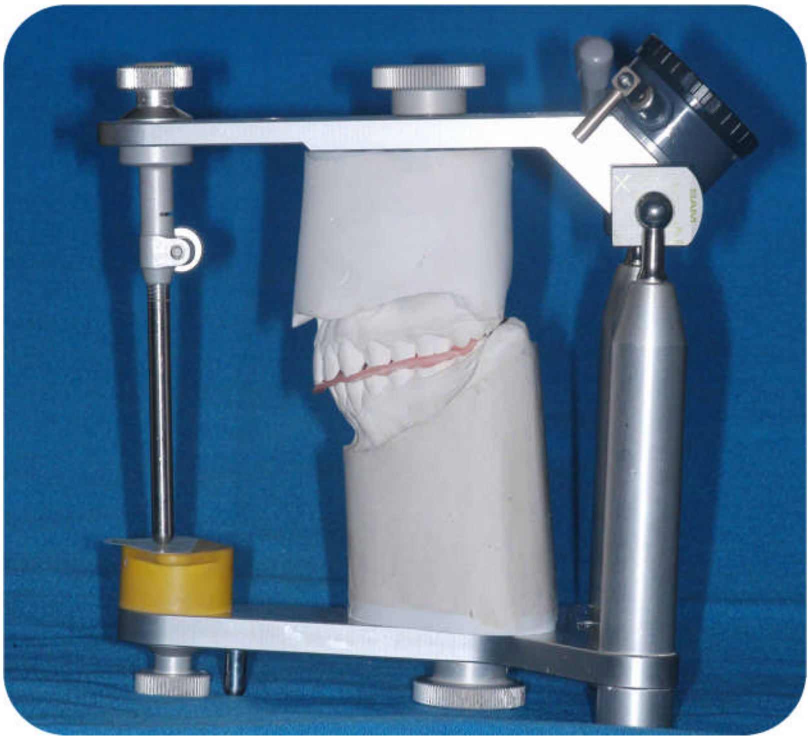


Fig. 14b : Step 4,5 &6

Fig.14 c: Step 7 & 8

Fig. 14 d : Step 9

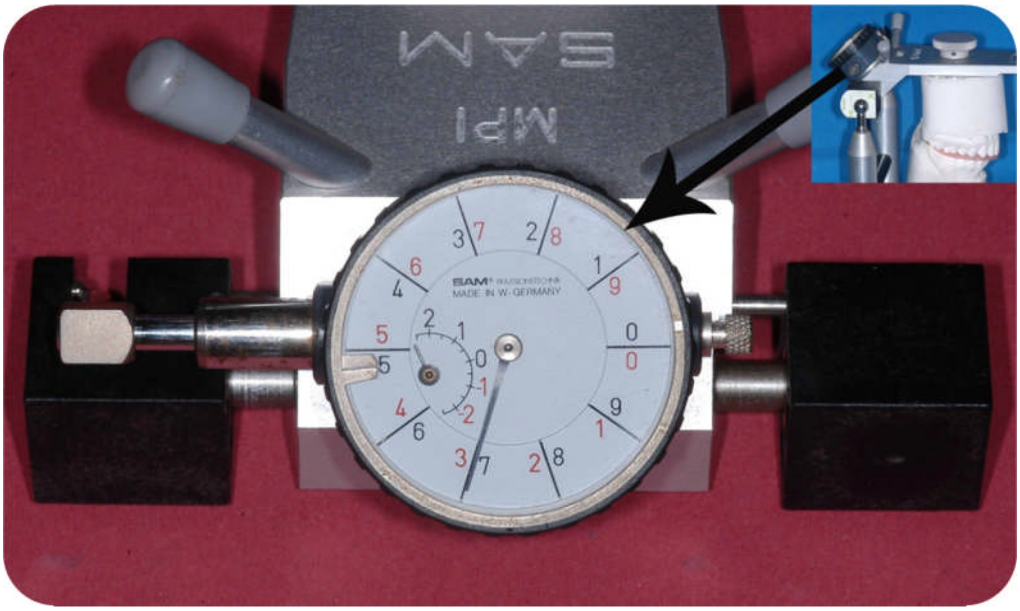


Fig. 14 e : Step 10

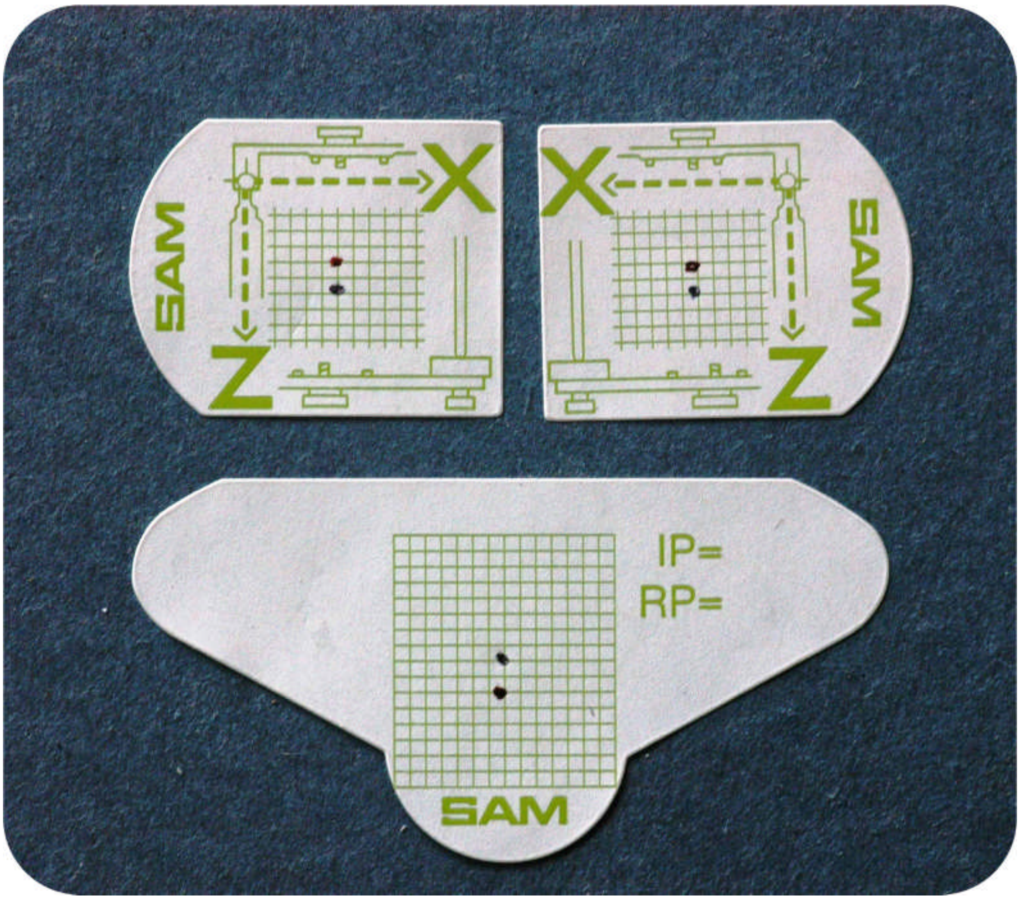


Fig. 14 f :Step 11 & 12 : Adhesive grids placed on the diagnostic sheet

RESULTS

- From the data obtained from MPI readings, a statistical analysis was employed to determine the percentage of the sample population with a difference between CR and MI.
- A Student's t-test was performed. The hypothesis being tested was that either there is a significant difference between MI and CR or, there is no significant difference.
- The statistical analysis was carried out in two parts. The first part tested the obtained values within the two groups, i.e. Extraction and Non-Extraction.
- The second part tested the obtained values between the same group, i.e. either Extraction or Non-Extraction.
- The level of statistical significance was set at p=0.05.
- If the value of 'p' › 0.05, then the inference is that there is no statistical difference between the variables being compared.
- However, if the value of 'p' ‹ 0.05, then the inference is that there is a statistical difference between the variables being compared.

I. Extraction- Non Extraction Group (Table II)

- Statistically significant difference were found in the Right, Left Vertical, horizontal and transverse MI-CR Readings. ($p < 0.001$)

II. Extraction Group (Table III)

- Statistically significant difference were found in the Right, Left Vertical, horizontal and transverse MI-CR Readings. ($p < 0.001$)

III. Non Extraction Group (Table IV)

- Statistically significant difference were found in the Right, Left Vertical, horizontal and transverse MI-CR Readings. ($p < 0.001$)

Extraction and Non - Extraction group (TABLE II)

- ✓ The mean vertical discrepancy:
  - 1.56 mm - right condyle
  - 1.22 mm - left condyle
- ✓ The mean antero-posterior discrepancy:
  - 0.80 mm - right condyle
  - 0.64 mm - left condyle
- ✓ The mean transverse discrepancy:
  - 0.67 mm
- ✓ The mean Delta H discrepancy:
  - -2.61 mm

- ✓ The mean Delta L discrepancy:
  - -2.5 mm

Extraction group: (TABLE III)

- ✓ ***The mean vertical discrepancy:***
  - 1.38 mm - right condyle
  - 1.04 mm - left condyle
- ✓ ***The mean antero-posterior discrepancy:***
  - 0.87 mm - right condyle
  - 0.65 mm - left condyle
- ✓ ***The mean transverse discrepancy:***
  - 0.69 mm

Non - Extraction group: (TABLE IV)

- ✓ ***The mean vertical discrepancy:***
  - 1.73 mm - right condyle
  - 1.40 mm - left condyle
- ✓ ***The mean antero-posterior discrepancy:***
  - 0.74 mm - right condyle
  - 0.64 mm - left condyle

- ✓ ***The mean transverse discrepancy:***

- 0.66 mm

- The ranges of CR – MI difference in both the group as determined from the MPI are summarized in Table I.

- The frequencies of CR - MI difference in the *antero-posterior plane (AP)* ***are*** summarized in Table V.

  1. 7 (23.3%) subjects on right side and 8 (26.7%) subjects on left side showed no measurable difference between CR - MI in the AP plane.
  2. 14 (46.7%) subjects on right side and 19 (63.3%) subjects on left side showed a condylar displacement between 0.01 and 1mm. between CR - MI in the AP plane.
  3. 8 (26.7%) subjects on right side and 2 (6.7%) subjects on left side showed a condylar difference between 1.01 and 2 mm. between CR - MI in the AP plane.
  4. 1 (3.3%) subjects on right side and 1 (3.3%) subjects on left side showed a condylar displacement more than 2 mm. between CR - MI in the AP plane.

- The frequencies of CR - MI difference in the *vertical plane* ***(SI)*** are summarized in Table VI

1. 3 (10%) subjects on right side and 2 (6.7%) subjects on left side showed no measurable difference between CR - MI in the SI plane.
2. 10 (33.3%) subjects on right side and 17 (56.7%) subjects on left side showed a condylar displacement between 0.01 and 1mm in the SI plane.
3. 12 (40.0%) subjects on right side and 7 (23.3%) subjects on left side showed a condylar difference between 1.01 and 2 mm. in the SI plane.
4. 5 (16.7%) subjects on right side and 4 (13.3%) subjects on left side showed a condylar displacement more than 2 mm. In the SI plane.

- The frequencies of CR - MI difference in the transverse plane are summarized in Table VII
    1. None of the subjects showed measurable difference between CR - MI in the transverse plane.
    2. 6 (20.0%) subjects showed a condylar displacement between 0.01 and 0.30mm On transverse plane.
    3. 7 (23.3%) subjects showed a condylar displacement between 0.30 and 0.50 mm. On transverse plane.
    4. 17 (56.7%) subjects showed a condylar displacement more than 0.50 mm. On transverse plane.

TABLE I The ranges of CR - MI difference in both the group as determined from the MPI.

Extraction Group									
Numbers	ΔH(mm)	ΔL(mm)	ΔX(mm)		ΔZ(mm)		ΔY(mm)		
			R	L	R	L	I	II	III
1	-3.5	-4	- 0.5	0.9	2	1	0.32	0.32	0.32
2	-4.5	-3	-2.1	-0.6	2.8	1.6	0.25	0.25	0.25
3	-1.5	-2.4	2	0	1.5	-0.8	-0.40	-0.41	-0.40
4	-2	-1.5	-0.5	0	1	0.8	-0.55	-0.55	-0.55
5	-4	-4	0	0.3	1.5	0.8	-0.35	-0.34	-0.34
6	-4	-2.5	-1.5	-0.8	2	2.5	1.10	1.10	1.10
7	-2	-1.5	-0.8	-0.9	1	1.4	-0.26	-0.26	-0.25
8	-3.5	-3	0	-0.5	2	1.1	-0.85	-0.85	-0.85
9	-2.5	-2.9	1.5	-0.8	1.5	0.2	-1.60	-1.60	-1.60
10	-2	-2.6	0.7	0	1	0.5	-0.70	-0.70	-0.70
11	-3.5	-2.6	-0.2	-0.4	1	2	0.82	0.82	0.82
12	-4	-2.8	1.5	-1.5	0	1.5	-0.15	-0.15	-0.15
13	-2	-3.2	-1.3	2	1	0.5	1.1	1.1	1.2
14	-1.5	-1	0	0.1	0	0	0.66	0.66	0.66
15	-3	-2.5	0.5	-1	2.5	1	-1.3	-1.3	-1.3

Contd.,

Non extraction Group									
Numbers	ΔH(mm)	ΔL(mm)	ΔX(mm)		ΔZ(mm)		ΔY(mm)		
			R	L	R	L	I	II	III
1	-4	-4	0	0	2	0.9	-0.4	-0.4	-0.4
2	-2.5	-2	-0.6	0	1.8	1	0.22	0.22	0.22
3	-3.5	-3	-1.8	-2.5	5	3	-0.36	-0.36	-0.36
4	-1	-1	-1	1	0.8	1	1	1	0.9
5	-2	-2.5	1	0.9	0.2	2	-0.3	-0.3	-0.31
6	2.5	-2	0	-0.9	1.5	0.5	0.25	0.25	0.25
7	-3	-2.6	0.5	-0.9	2.4	1	-1.2	-1.2	-1.2
8	-7	-6	-1.5	-1	4.5	4.5	0.77	0.77	0.77
9	0	-1	-1	1	-1.5	-0.5	1.1	1.1	1.1
10	-2	-1.5	0.6	0	1	0.9	-0.5	-0.5	-0.5
11	4	-3	-1	0	1.5	1	0.5	0.5	0.52
12	-1	-2	0	0.5	0.9	2	1	1	1.1
13	-4	-2.8	-1.4	-0.8	1.9	2.4	1	1	1
14	-2	-2.6	0.7	0	1	0.4	-0.65	-0.65	-0.66
15	-1.5	-1	0	0.1	0	0	-0.65	-0.65	0.65

TABLE II Independent t-test for mean deviations from central point for all cases.

Variable	N	Mean	SD	t-value	p-value	95% CI for Mean	
						Lower	Upper
ΔH	30	-2.617	1.080	-13.267	<0.001	-3.020	-2.213
ΔL	30	2.500	1.602	8.550	<0.001	1.902	3.098
ΔX Right	30	0.807	0.648	6.824	<0.001	0.565	1.048
ΔX Left	30	0.647	0.617	5.737	<0.001	0.416	0.877
ΔZ Right	30	1.560	1.128	7.572	<0.001	1.139	1.981
ΔZ Left	30	1.227	0.962	6.984	<0.001	0.867	1.586
ΔY	30	0.677	0.379	9.792	<0.001	0.536	0.818

TABLE III Independent t-test for mean deviations from central point for Extraction group.

Variable	N	Mean	SD	t-value	p-value	95% CI for Mean	
						Lower	Upper
ΔH	15	-2.900	1.021	-10.998	<0.001	-3.466	-2.334
ΔL	15	2.300	1.568	5.681	<0.001	1.432	3.168
ΔX Right	15	0.873	0.724	4.675	<0.001	0.473	1.274
ΔX Left	15	0.653	0.574	4.406	<0.001	0.335	0.971
ΔZ Right	15	1.387	0.802	6.699	<0.001	0.943	1.831
ΔZ Left	15	1.047	0.669	6.064	<0.001	0.676	1.417
ΔY	15	0.694	0.431	6.230	<0.001	0.455	0.933

Note: If p value is <0.05 then the difference between the mean values are statistically significant. Otherwise the mean difference is not statistically significant.

TABLE IV Independent t-test for mean deviations from central point for Non-Extraction group.

Variable	N	Mean	SD	t-value	p-value	95% CI for Mean	
						Lower	Upper
ΔH	15	-2.333	1.097	-8.241	<0.001	-2.941	-1.726
ΔL	15	2.700	1.664	6.285	<0.001	1.779	3.621
ΔX Right	15	0.740	0.579	4.949	<0.001	0.419	1.061
ΔX Left	15	0.640	0.678	3.656	< 0.003	0.264	1.016
ΔZ Right	15	1.733	1.390	4.831	<0.001	0.964	2.503
ΔZ Left	15	1.407	1.184	4.603	<0.001	0.751	2.062
ΔY	15	0.660	.332	7.696	<0.001	0.476	0.844

TABLE V The frequencies of CR - MI difference in the *antero-posterior plane (AP).*

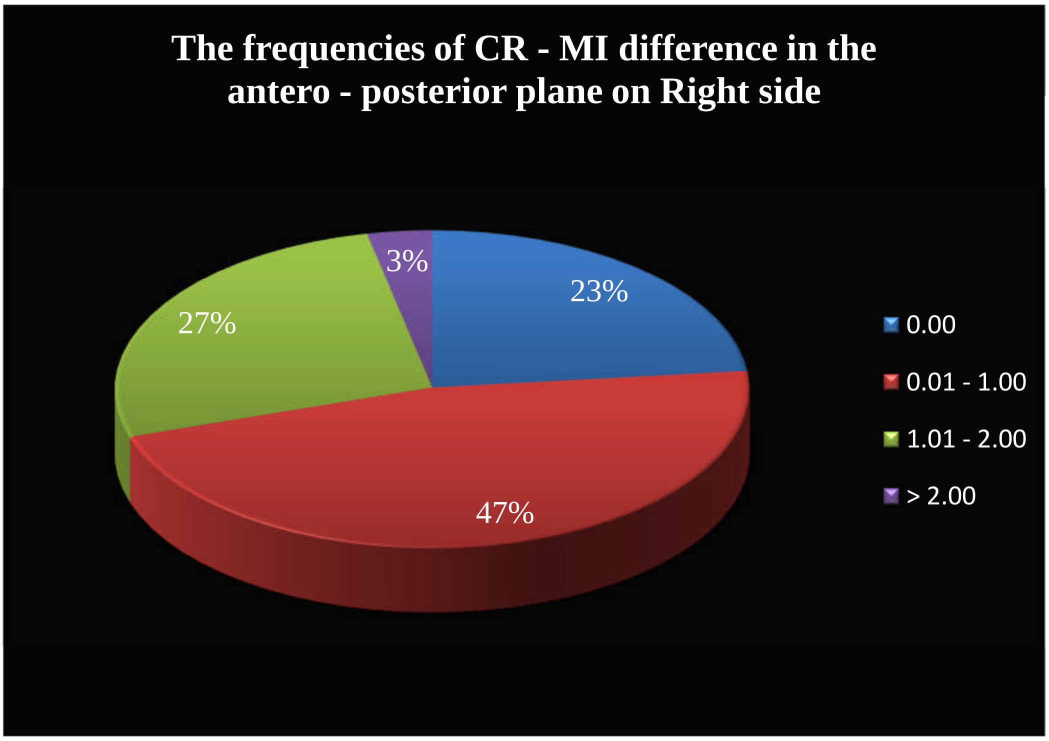
Interval	ΔX Right		ΔX Left	
	n	**%**	**n**	**%**
0	7	23.3	8	26.7
0.01 - 1.00	14	46.7	19	63.3
1.01 - 2.00	8	26.7	2	6.7
> 2.00	1	3.3	1	3.3
Total	30	100.0	30	100.0

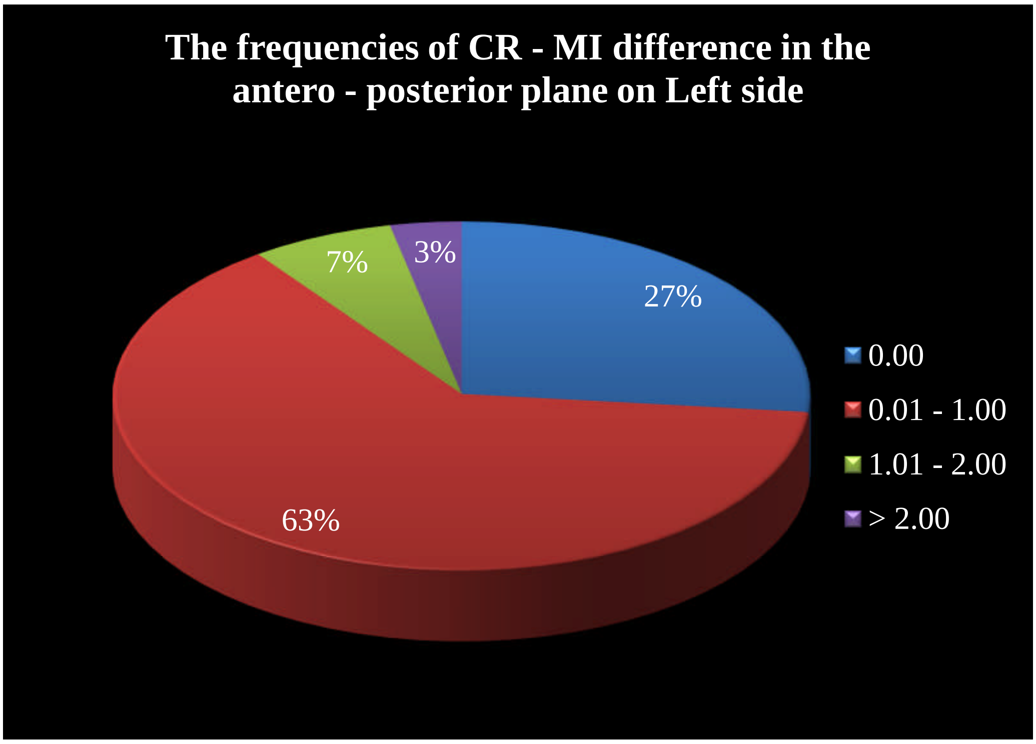
TABLE VI* The frequencies of CR - MI difference in the *vertical plane (SI)

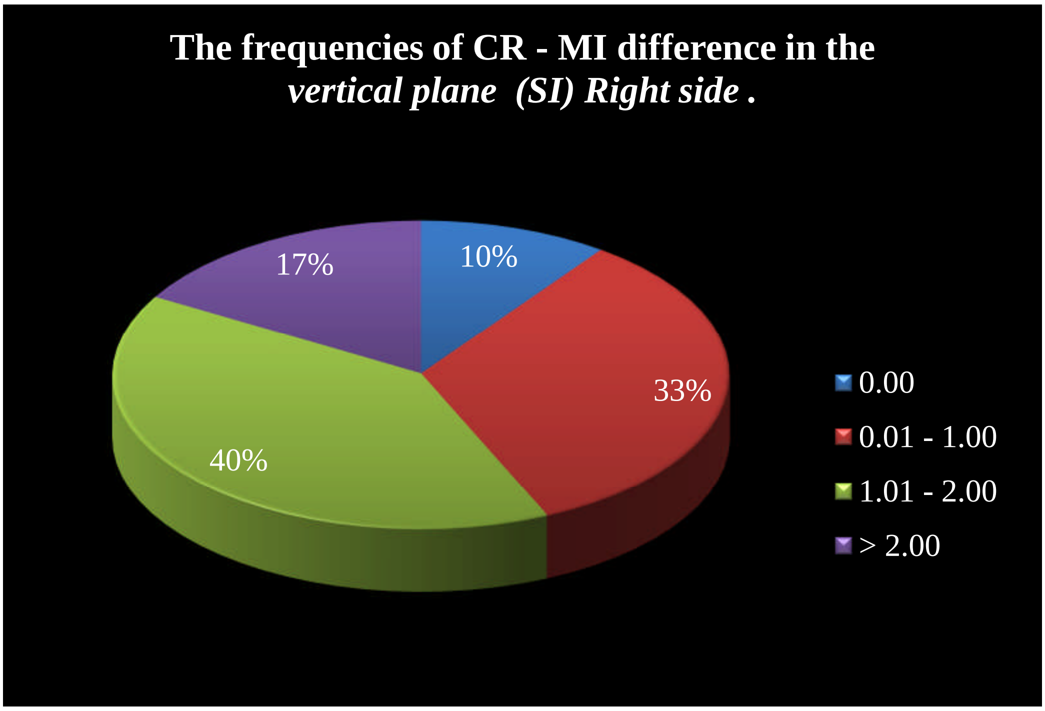
Interval	ΔZ Right		ΔZ Left	
	n	**%**	**n**	**%**
0	3	10.0	2	6.7
0.01 - 1.00	10	33.3	17	56.7
1.01 - 2.00	12	40.0	7	23.3
> 2.00	5	16.7	4	13.3
Total	30	100.0	30	100.0

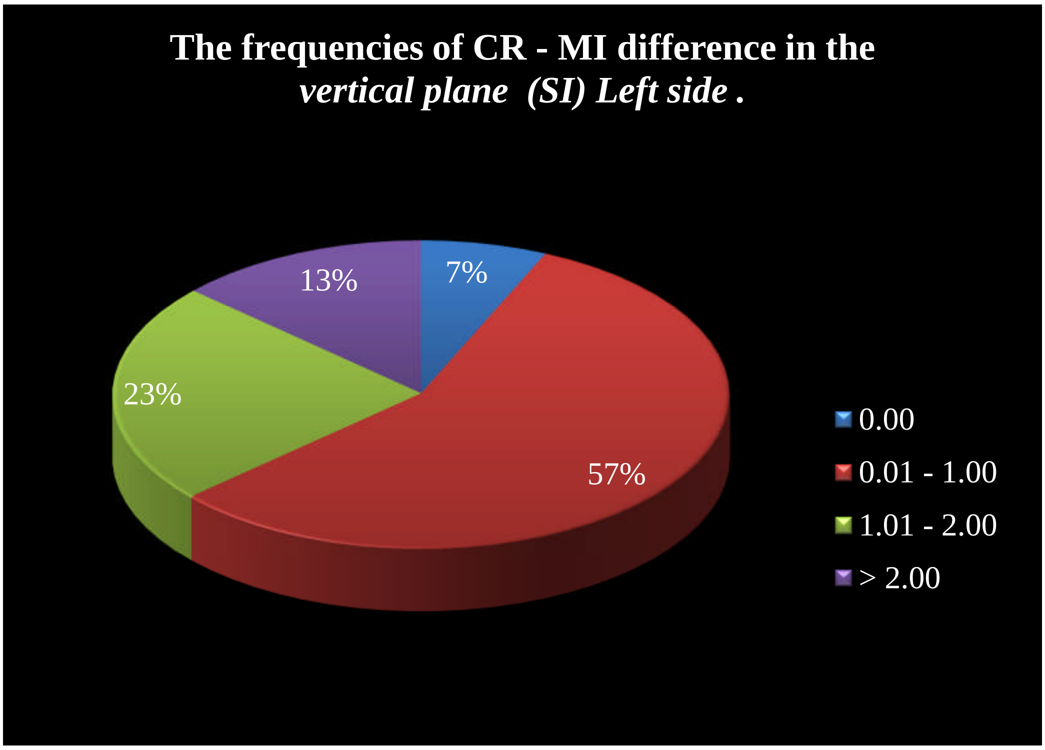
TABLE VII The frequencies of CR - MI difference in the transverse plane.

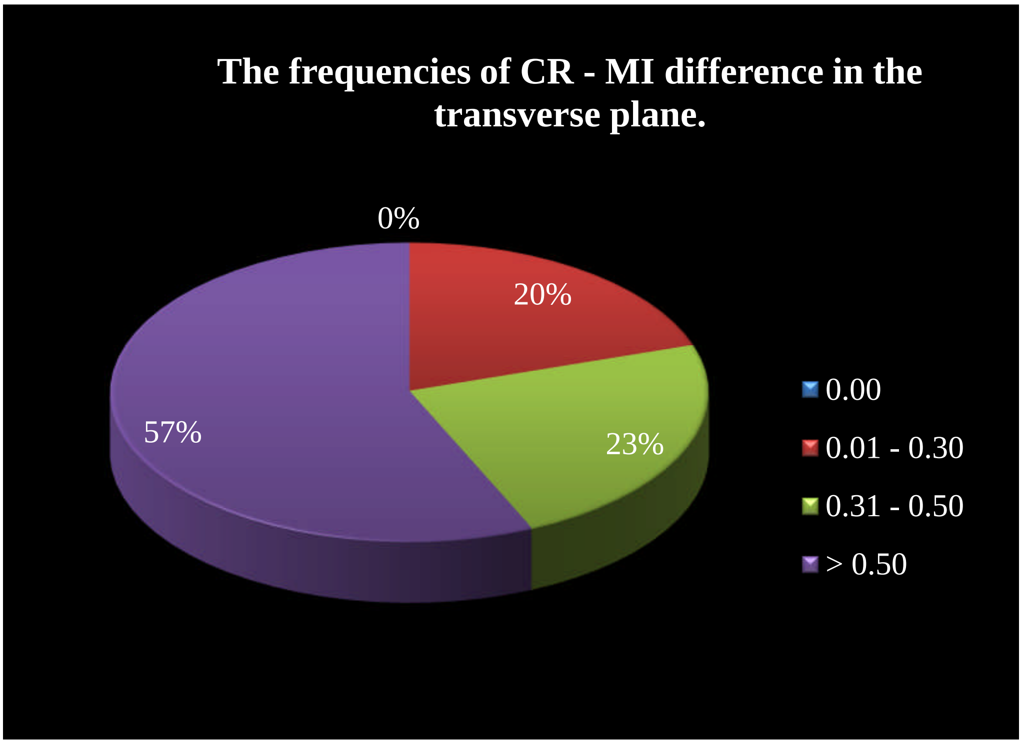
Interval	**ΔY**	
	n	**%**
0	0	0.0
0.001 - 0.300	6	20.0
0.3001 - 0.500	7	23.3
> 0.500	17	56.7
Total	30	100.0

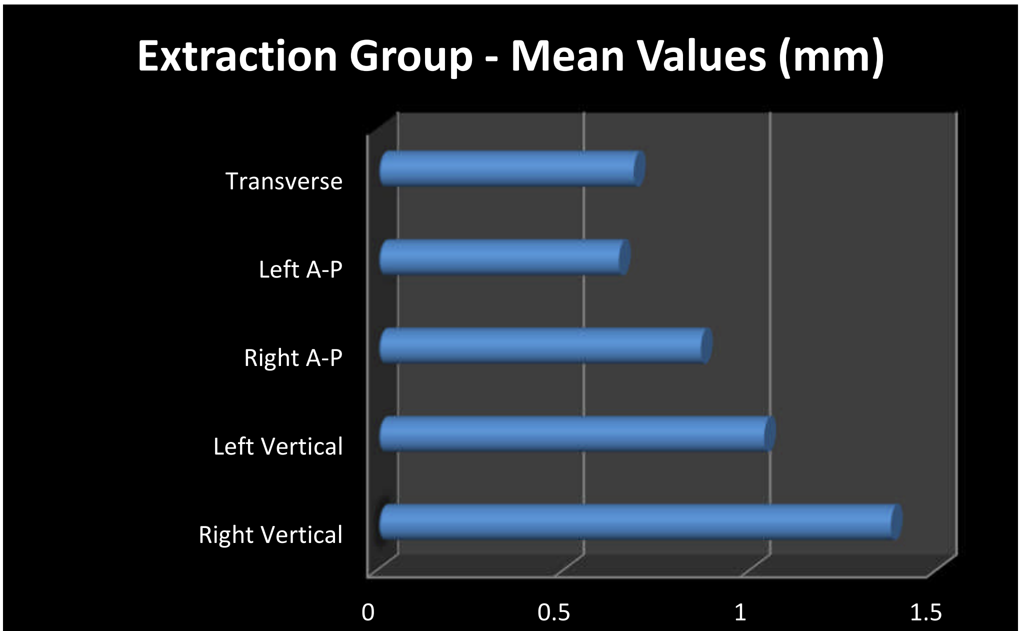

The frequencies of CR - MI difference in the antero - posterior plane on Right side
3%
23%
27%
47%
0.00
0.01 - 1.00
1.01 - 2.00
> 2.00


The frequencies of CR - MI difference in the antero - posterior plane on Left side
7%
3%
27%
63%
0.00
0.01 - 1.00
1.01 - 2.00
> 2.00

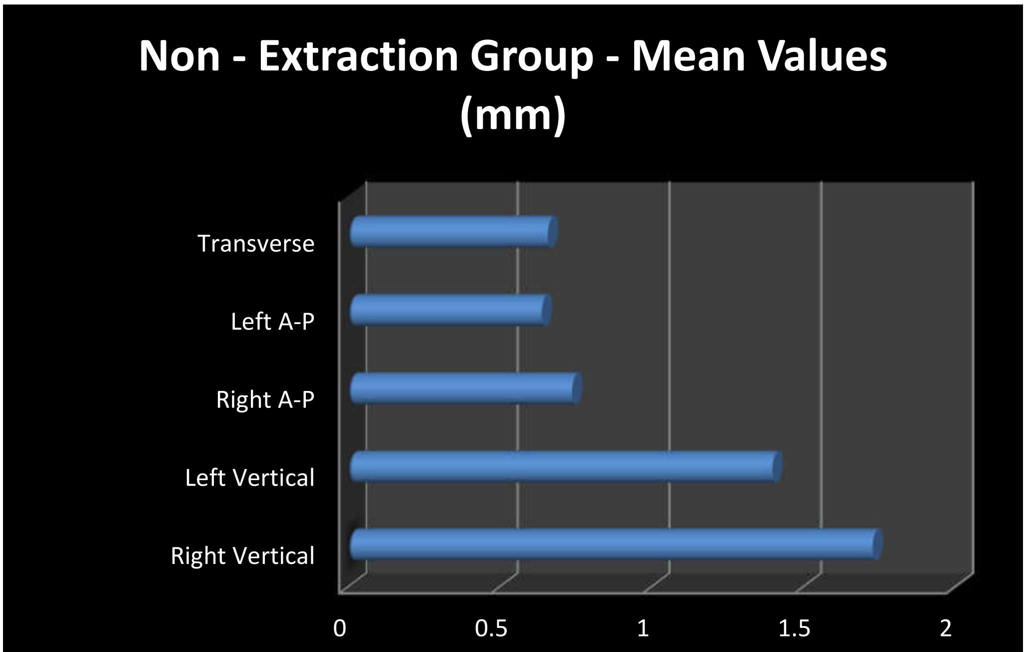

The frequencies of CR - MI difference in the
vertical plane (SI) Right side .
10%
33%
40%
17%
0.00
0.01 - 1.00
1.01 - 2.00
> 2.00


The frequencies of CR - MI difference in the
vertical plane (SI) Left side .
7%
57%
23%
13%
0.00
0.01 - 1.00
1.01 - 2.00
> 2.00

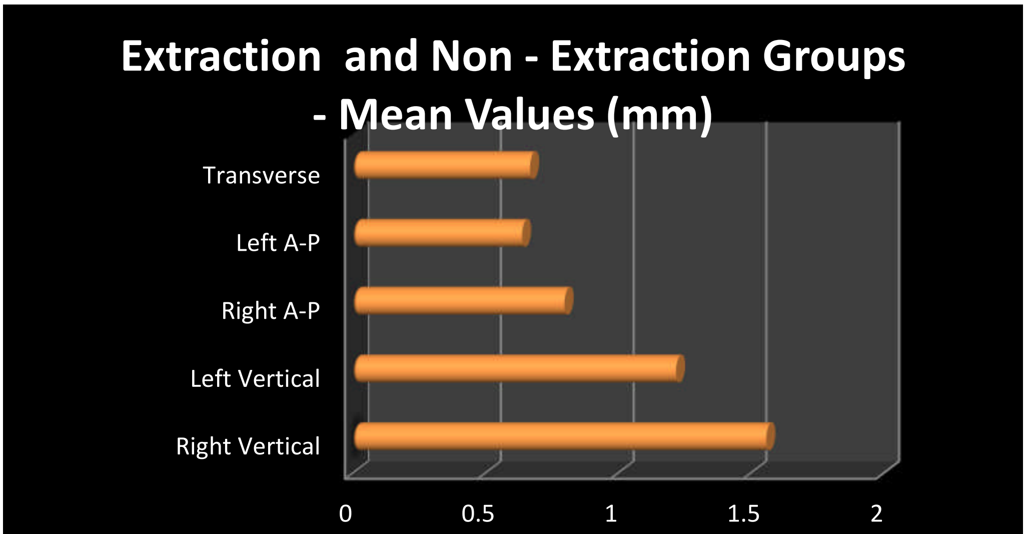




	Right Vertical	Left Vertical	Right A-P	Left A-P	Transverse
Extraction group - mean values	1.38	1.04	0.87	0.65	0.69



	Right Vertical	Left Vertical	Right A-P	Left A-P	Transverse
Non - Extraction group - mean values	1.73	1.4	0.74	0.64	0.66



	Right Vertical	Left Vertical	Right A-P	Left A-P	Transverse
Extraction and Non - Extraction groups - mean values	1.56	1.22	0.8	0.64	0.67

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